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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

Initiation Fees		*Annual Dues*	
Members	$ 5.00	Members	$ 6.00
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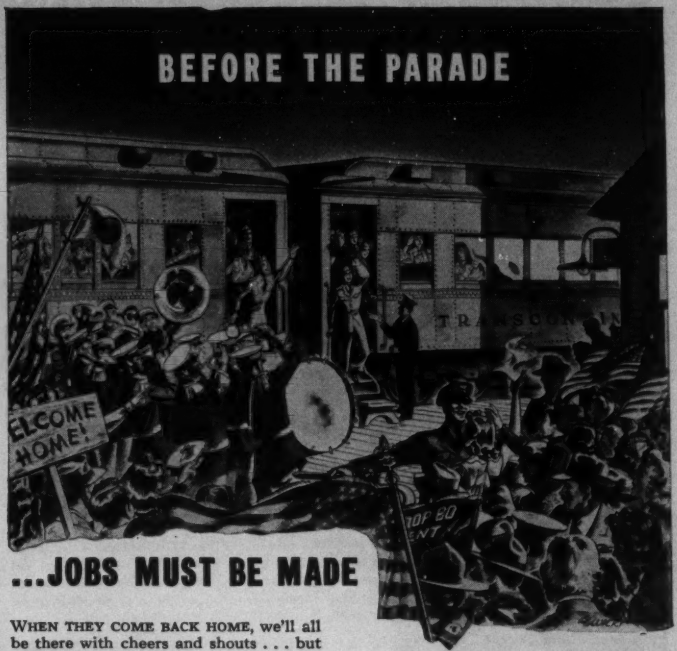
This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September on such date as the Executive Committee may designate.



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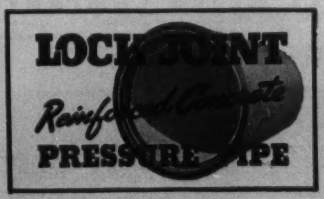

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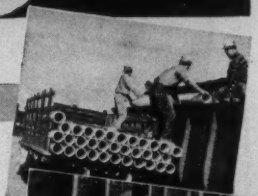

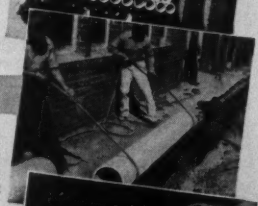

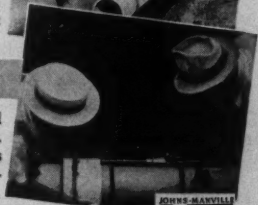

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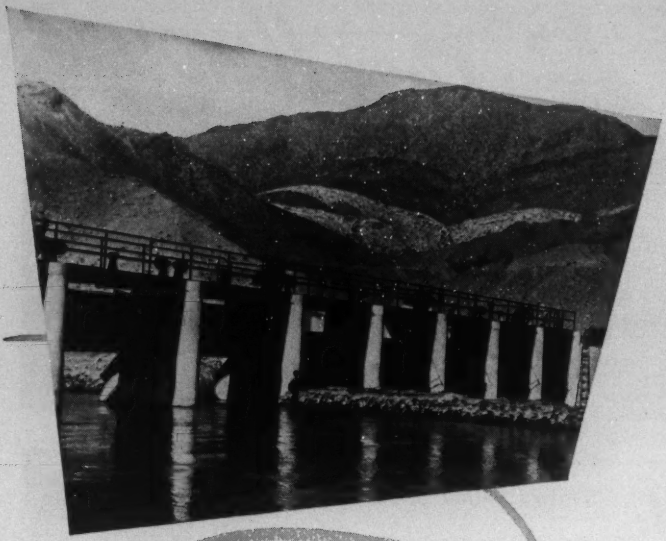

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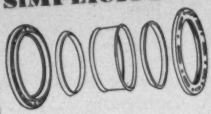

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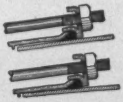

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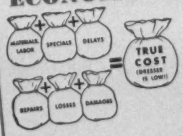

The true cost of a pipeline is not the first cost in material and labor—but the *total* cost over the life period. Dresser Couplings give lowest cost *over the years*.

DRESSER COUPLINGS

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SCHUYLKILL WATER WORKS, PHILADELPHIA, PA. 1840.
From an engraving by J. C. Armytage based on a drawing by W. H. Bartlett.

New England Water Works Association
ORGANIZED 1882

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SCHUYLKILL WATER WORKS AT PHILADELPHIA, 1840*

FROM AMERICAN SCENERY; OR, LAND, LAKE AND RIVER ILLUSTRATIONS OF TRANSATLANTIC NATURE.

From Drawings by W. H. Bartlett,

Engraved in the First Style of the Art,

BY R. WALLIS, J. COUSEN, WILLMORE, BRANDARD, ADLARD, RICHARDSON, ETC.

The Literary Department

BY N. P. WILLIS, ESQ.

Author of "Pencillings by the Way," "Inklings of Adventure," etc.

Vol. II. London: George Virtue, 26, Ivy Lane. MDCCCXL, p. 71.

The Water-works of Philadelphia rank among the most noble public undertakings of the world. The paucity of water in the city first set to work the sagacious mind of Dr. Franklin, who, by will, bequeathed a portion of a long accumulated legacy to bring a greater supply of this necessary element from Wissahiccon Creek. This was found, after a while, to be insufficient; and a plan was proposed, and carried into operation, to form a reservoir on the east bank of the Schuylkill, from which water was to be thrown by a steam-engine into a tunnel, conveyed to a central position, and raised by a second engine to a higher reservoir, which supplied all the pipes in the city. An experience of ten years satisfied the corporation that a sufficient supply could not be obtained by this method. The steam-engines were liable to frequent accidents, and the derangement of one stopped the supply of the whole city. After several other futile experiments, the present extensive yet simple water-works were proposed, and three hundred and fifty thousand dollars voted at once by the city corporation for the commencement of the undertaking.

*Editor's Note: The Schuylkill Water Works are among the first great water works of America and so they are deserving of acquaintance by water works men. This description by a layman is especially worthy of note.

The Schuylkill opposite Philadelphia, is about nine hundred feet in breadth. It is subject to sudden *freshets,* (an American word, unknown in this use in England, and meaning an overflow of a river current,) but its average depth is thirty feet at high water. It was necessary to back the river up about six miles; and a dam was then created by cribs and masonry, running diagonally across, with several ingenious contrivances to prevent damage by ice and spring freshets. A overfall of one thousand two hundred and four feet, forming a beautiful feature of the scenery, is thus created, and a water-power upon the wheels sufficient to raise eleven millions of gallons in twenty-four hours. The reservoirs, elevated above the top of the highest house in the city, crown the ornamental hill which overhangs the river at this place; and water can thus be conveyed to every quarter of Philadelphia, and made to spring, as if by a magic touch, in the highest chamber of the inhabitant. It is of a deliciously soft and pleasant quality; and those who are habituated to wash in the "city of brotherly love," are spoiled for the less agreeable lavations afforded by other towns in America.

Fair Mount is a beautiful spot; and standing, as it does, just on the skirt of the town, it serves the additional use of a place of pleasant and healthful public resort. The buildings containing the pump-rooms have considerable pretensions to architecture; and the *facades* and galleries extend along the river, forming a showy object from every point of view, but from the absence of any grande design in the whole, failing of a general fine effect, and presenting what a Londoner would call rather a teagardenish appearance. Steps and terraces conduct to the reservoirs, and thence the view over the ornamented grounds of the country seats opposite, and of a very picturesque and uneven country beyond, is exceedingly attractive. Below, the court of the principal building is laid out with gravel walks, and ornamented with fountains and flowering trees; and within the edifice there is a public drawing-room, of neat design and furniture; while in another wing are elegant refreshment-rooms—and, in short, all the appliances and means of a place of public amusement.

It may as well be remarked here, that this last advantage is less improved in America than it would be in any other country. The Water-works of Fair Mount, though within fifteen minutes' walk of

every citizen's dwelling in Philadelphia, are (comparatively to its capacities) unfrequented. In several visits made to them in fine weather, we scarce saw more than three or four persons in the grounds; and those seemed looking for other company, more than enjoying the refreshing fountains and lovely prospects around them. As a people, we have no habit of amusement in America. Business and repose are the only two states of existence we know. How far Europeans have the better of us in this respect—how much our morals improve, or our health suffers, from the distaste for places of public relaxation and resort, are questions the political economists have not yet condescended to settle.

STORROW'S TREATISE ON WATER WORKS, 1835.

BY GORDON M. FAIR*

[*Received March 1, 1945.*]

Among early books on Water Works Engineering "A Treatise on Water Works" by Charles Storer Storrow occupies a high place, because it first gave to English-speaking engineers the results of tests made by French engineers and their methods for solving problems on the flow of water in pipes and open channels. Storrow's unusual training fitted him to perform this service. Born March 25, 1809, he had received his early education in France before entering Harvard College with the class of 1829. After graduating first in his class, he determined to adopt the profession of civil engineering. Since no engineering school was in existence in this country, he studied for a brief time in the library of the eminent civil engineer Loammi Baldwin before returning to France to attend the École des Ponts et Chaussées in Paris. This privilege he secured through the influence of General Lafayette who was a close friend of his father's family.

In 1832, Storrow came back to the United States and was employed on the construction of the Boston and Lowell Railroad of which James F. Baldwin was chief engineer. While engaged on this work, Storrow devoted his leisure to the preparation of "A Treatise on Water Works." This small volume, 242 pages in length, was published in Boston in 1835 by Hilliard, Gray and Co. The printer was Charles Folsom of Cambridge.

In 1845, at the request of Abbott Lawrence, Storrow became treasurer, engineer, and agent of the Essex Company which built the canals, mills, and indeed the very city of Lawrence. He maintained his affiliation with the Company until he reached the age of eighty. He died in Boston in 1904 in his ninety-sixth year.

The full title of Storrow's book is: *A Treatise on Water Works for Conveying and Distributing Supplies of Water; with Tables and*

*Abbott and James Lawrence Professor of Engineering and Gordon McKay Professor of Sanitary Engineering, Harvard Graduate School of Engineering, Cambridge, Mass.

Examples. The work includes a preface, an introduction, ten chapters, and an appendix.

Much space in the body of the book is devoted to hydraulic formulas and tabulation. Chapters I and II deal respectively with the theory of motion of water in open channels and in pipes. Chapters V and VI apply the formulas developed for the conveyance of water by canals, aqueducts, and pipes. Chapter IV discusses means for measuring the flow of water; Chapter IX treats of pipes of different diameters and *jets d'eau**; and the appendix presents information on weights and measures, as well as useful conversion units. Abstracts from the remaining chapters are believed to be of special interest as reflecting the status of the art of water supply in 1835. They will be allowed to speak for themselves.

Quotations from Storrow's Treatise

Introduction. An abundant supply of pure and wholesome water is every where one of the first requisites for health, cleanliness, and comfort. It is especially so in crowded cities, where, in addition to the quantity required for domestic purposes, it is highly important to possess a sufficient supply to check the progress of conflagration, to cleanse the streets from the accumulation of offensive matters, and to purify and cool the air by a copious distribution from fountains and *jets d'eau.*

The art of supplying the deficiency of nature by conveying this precious element in plentiful streams from a distant source, does not owe its origin to the luxury of modern times, as is the case with so many of the arts, which now minister to our physical enjoyment. On comparing the hydraulic works of the ancient Romans with those erected within a comparatively recent period, we find them still unsurpassed in grandeur and magnificence. At a wonderful expense of labor, they carried their aqueducts through hills and over valleys, in spite of every natural obstacle; and it will give some idea of the scale on which these noble monuments were constructed, to mention, that, according to the *Commentary* of Frontinus, who, in the year 98, had the direction of the nine aqueducts by which water was conveyed to Rome, their united length amounted to 250 miles, and their daily supply to more than 27,000,000 cubic feet. This author adds, that the

*These would be called nozzle streams today.

supply might have been doubled by proper care to prevent fraudulent usage.

Nor was it for the Imperial city alone, that the Romans sought to procure this blessing. In the various provinces of their empire they constructed works of the same kind on the same magnificent scale. Similar achievements are not to be expected at the present day, when happily it is no longer the prerogative of a single nation to wield the strength and apply the resources of the whole civilized world. But it is the boast of modern science, that it supplies the want of immense physical forces by the most ingenious application of the means which it can command; and, instead of overcoming obstacles, as was once done, by dint of the combined and persevering labor of thousands, it skilfully eludes the difficulties which lie in its path, and finds its glory no less in the feebleness of the means by which it accomplishes great objects, than in the importance of the objects themselves.

It seems hardly necessary to enlarge upon the advantage to be derived from a careful consultation of the most improved theory, when there is any question of constructing works of the kind which we have been describing. At the present day, when we see so many ways of applying the wealth and resources of civilized communities to the amelioration of their condition, and the partisans of each are loudly proclaiming its superior advantages, it is of the greatest importance not to waste in rash and hasty enterprises those means, which, employed in some other manner, might have been productive of happy effects. When there is no experiment to furnish a guide, the object of theory is, to direct us to those measures, which have the highest probability of success to recommend them; and when we have the benefit of previous experiments, it teaches us the proper manner of employing them, by pointing out the anomalies, and showing us how to distinguish the influence of the various causes, which act in combination.

That part of the science of Hydraulics, of which the construction of water-works is an immediate practical application, has, from its importance, engaged the attention of many eminent men; and there are few more beautiful examples of the application of mathematical analysis to the discovery of physical truths, than are to be found in the writings of some of them. Though very far from having reached that perfection to which the labors of subsequent experi-

menters will undoubtedly carry the science, yet the results already obtained are so satisfactory, that it would be folly to neglect them, before the united efforts of theory and practice have furnished us with a safer guide. It is true, that many experiments are yet to be desired in order to confirm some of the results which theory alone has yet announced. The formulae recently given by Bélanger should be subjected to this test, and also the rules given for calculating the motion of water which flows through a system of branch pipes. The engineers having charge of the various hydraulic works, which will doubtless ere long be commenced in this country, as the principal cities increase in wealth and population, and feel more and more the necessity of procuring ample supplies of water, will find many opportunities of adding to the experimental results which we already possess; and it should be remembered that even a single experiment, carefully and judiciously made and faithfully reported, is a valuable present to science. We see this strikingly, when we read some of the early works on hydraulics. The *theories* of the authors have in many instances been entirely exploded, or greatly modified and improved, by later inquirers; but their *experiments* can never grow old. Until the laws of nature lose their permanency, what was a fact in one age is equally a fact in another, and no succeeding observations can set it aside.

The object of the present treatise is, to exhibit known results in as simple a manner as possible, and to show their application as required by the Engineer charged with the execution of hydraulic works. It seems proper to begin by briefly recounting the various steps, by which this branch of science has advanced to its present state, and we shall do this in a small compass. We shall afterwards give an exposition of the theory of the motion of flowing waters, taken from the works of Prony, Eytelwein, and Bélanger, by whom it has been chiefly perfected, and then proceed to the practical application of the principles thus established.

Chapter III. General Remarks on the Means of Supplying Cities with Water.

When a large city is to be supplied with water, the first step to be taken is, to make a general survey of the neighboring country,

in order to ascertain whence a sufficient *quantity* can be obtained. It is of the utmost importance that the source should be so abundant as to furnish the requisite quantity even in seasons of drought; for the evils of a temporary interruption, after the inhabitants have been led to depend upon a regular supply, are so great that they must at any expence be avoided. According to the localities, recourse may be had to a stream, if there be any in the neighborhood, or to ponds of limpid water, which may be increased in abundance by turning the neighboring brooks into them; or artificial ponds may be formed by damming the outlet of a valley, and collecting in it the supplies from the various small streams which convey the waters which fall upon the higher grounds.

The quantity of rain, upon which of course depends the greater or less abundance of the streams, may be an element of some importance to determine. It varies much in different localities.

The topography of the country will show to a certain extent what supplies the ponds will be likely to derive from rain.

In order to ascertain the quantity which may be drawn from a river, recourse must be had to various methods of gauging its discharge per second, which will be shown in the following chapter.

The quantity of water necessary for a certain population does not admit of being determined with mathematical precision; since independently of what is required for domestic use, an additional quantity may be wanted in various mechanic arts.

It is also indispensable to ascertain accurately the *quality* of the water. Water may be either *hard* or *soft*. The hardness generally proceeds from saline matters or from the presence of gas. Dr. Saunders observes* that it depends chiefly upon the sulphate and carbonate of lime held in solution; and that when these earthy salts exist in the proportion of five grains to a pint, such water will be hard. The dissolving power of hard water is less than that of soft; soap does not completely dissolve in it, but appears in a sort of curdled or coagulated state; hence it is less fit for washing, bleaching, dyeing, etc. It is also less powerful in softening the texture of vegetable leaves. Soft water has no saline or other taste, is inodorous, and dissolves soap completely. It is much to be preferred for softening the

*Rees's Cyclopædia.

texture of animal or vegetable matters and for all culinary purposes, as well as for washing. M. Thénard says that water may be considered as good for domestic uses, when it is but slightly affected by nitrate of barytes, nitrate of silver, or oxalate of ammonia; and when, upon being evaporated, it leaves but a very small residuum.

These two important preliminaries as to *quality* and *quantity* being satisfactorily settled, the localities will show which should be preferred, of the various methods which present themselves for disturbing the supply. Whether the water be brought from a distant and elevated source, or immediately raised by machinery, the most common method is, to collect it in one or more large reservoirs situated upon elevated spots, and thence to distribute it through the streets and into the premises of individuals by means of pipes, through which it flows in virtue of its hydrostatic pressure. In some instances, however, it has been forced directly into the mains which carry it though the various quarters of the city. This last method dispenses with the cost of the construction of reservoirs, and may, in some cases, be the most economical in the first instance, but it is less regular in its operation than the other. A reservoir maintains a constant head upon the pipes, and a large body of water in reserve in case of emergency. Should an extensive fire occur, the pipes from a reservoir are at any instant in a state to do service, while it would often take some time to get the steam up, or to set other machinery in motion. Experience has proved the truth of these remarks at the London Water Works. Another great advantage of reservoirs is, that the water has time to settle and deposit the impurities which it may hold in suspension.

When water is to be brought from a distance, we may make use of pipes, aqueducts of masonry, or canals opened in the natural ground. If the distance be very considerable, there would seem to be an advantage in aqueducts and canals; for the resistance which is developed in pipes of great length, diminishes the discharge in a very great degree; especially as in following the natural undulations of the ground, which must be done unless much money is laid out in trenching and embanking, there will be an increase of length and a diminution of discharge, which, our formulae have shown us, attend upon every deviation from a straight line. On the other hand,

pipes have the advantage of being out of the reach of the extremes of temperature, and, where the distance is not very considerable, will generally be the cheapest.

A canal in the natural ground, like an aqueduct, has the advantage of bringing a very much larger supply with but little fall. But it will generally require some time to saturate the bed so that there shall be no leakage; and it is difficult to preserve the water in as pure a state, and to protect it from animals and trespassers. It may pass through saline or calcareous earths, and thus, though naturally good, may contract a disagreeble taste or odor. In most countries it is liable to be frozen in winter. Evaporation, too, is a great source of loss, which it is impossible to avoid. Numerous experiments are needed to enable us to determine the quantity which passes off in this manner from large sheets of water. Most of those hitherto made have been on very small quantities, and it is easily conceived that these cannot give a correct idea of the effects upon surfaces of considerable extent. Smeaton says (Reports, Vol. II.) that when deep standing waters lose by exhalation to the amount of ten inches perpendicular, it must be in a long drought of three or four months' continuance. Messrs. Sédileau and Cotte found, that at Paris the mean annual evaporation amounts to 34 inches, the mean annual quantity of rain being 21 inches. Messrs. Clausade and Pin found that the waters of the Languedoc Canal and the basin of St. Féréol, lose yearly from 30 to 32 inches by evaporation, the annual quantity of rain being about 31 inches.

From a careful consideration of all the circumstances we have enumerated, according as their influence is counteracted or increased by local causes, the engineer must determine upon the most secure and economical mode of supply.

Chapter VII. Of Pumps

When there is in the immediate vicinity of a city a river or lake, whose waters need only to be raised to such a height as to procure a sufficient head for their distribution in the most elevated quarters of the city, pumps may be used with great advantage. Whether the motive power be a steam-engine, or a water-wheel, or any other which circumstances may render preferable, the construc-

tion of the pumps is essentially the same. There are two kinds of pumps, the *lifting* and the *forcing* pump, which we will now proceed to describe.

Chapter X. Artesian Wells

It seems not improper in this place to give some account of what are called *Artesian Wells*, of subterraneous springs whose waters, when they have been reached by boring from the surface, rise and maintain a much higher level than that at which they were first found. A description of the various instruments to be used in the process of boring belongs to a special treatise on this subject, such as those of Garnier and Héricart de Thury. But some information respecting the nature and geological position of the strata, where these rising springs are to be met with, will enable us to judge of the probable success of boring, before undertaking expensive operations. What we have to say on this subject will be taken from the work of Garnier, for which the author received a prize from the *Société d'Encouragement pour l'Industrie Nationale* of France, and which was published by order of the French government in 1822.

REAL ESTATE ACQUISITIONS FOR METROPOLITAN BOSTON'S WATER SUPPLY

BY JAMES A. CHRISTENSON†

[*Read March 15, 1945.*]

The newest addition to Metropolitan Boston's water supply was started in 1926 to relieve frequent, dangerous low-level stages of Wachusett Reservoir, and like the "stitch in time" sufficient progress had been made so that in March 1931, it was possible to divert from the Ware River an ample quantity of water to relieve a serious shortage then threatening the people of Greater Boston.

The portion of this vast project lying west of Wachusett Reservoir, including Quabbin Reservoir, the Ware River Intake Works, and Quabbin Aqueduct Tunnel devoted to collection and storage of additional water for the District's needs, limits this supplementary paper. The original paper, published in this Journal,"* recited facts and figures based on conditions on May 31, 1939. It is the purpose of the present paper to modernize the account, basing figures on the data as of November 30, 1944. Although a few settlements are still pending, the amounts involved are small and can be discounted for practical purposes.

The policies and methods of the Commission relative to real estate acquisition have not changed materially, but additional purchases have been made with consequent increase in acreages and costs. Final costs and some of the important activities of the past five years will be summarized, following in a general manner the outline of the original account.

Swift River Watershed

This watershed above Winsor Dam plus that of Beaver Brook above Quabbin Dike contains 186.0 sq. mi. Quabbin Reservoir with a surface area of 38.6 sq. mi., when full, amounts to about 21% of

†Civil Engineer, Boston, Mass.
*Vol. 54 (1940) p. 194.

the total watershed, and will contain, when Elev. 530 is reached, 415 billion gallons. This storage is subject to regulations of the War Department, certain releases being required for purposes of navigation in the lower Connecticut River.

A superstructure constructed at the outlet of the diversion tunnel below Winsor Dam houses the controlling equipment of the waters discharging from Quabbin Reservoir. This regulation will give downstream users of Swift River flow two advantages: A guaranteed minimum flow of 20 mgd, and the practical certainty of protection from flood calamities. Plans have been made for the installation of a 1700-hp water wheel and electric generator to recover the energy in the water released from the dam.

Page 197, Line 30. Since the 1939 report, the Administration Road in the Town of Ware has been constructed. This scenic road built under a PWA contract connects Winsor Dam Spillway Weir Road (Figure 1) with the Quabbin Dike Access Road. Included in the contract was a parking area at the foot of the fire look-out tower (Figure 2) on the summit of Quabbin Hill, and the spur road connection with Administration Road. This total additional road length is 3.98 mi.

FIG. 1.—WINSOR DAM SPILLWAY WEIR ROAD LOOKING NORTH.

FIG. 2.—PARKING AREA AND FINE LOOK-OUT TOWER ON THE SUMMIT OF QUABBIN HILL.

Access roads in the towns of Belchertown, Hardwick, New Salem and Petersham were improved under a PWA contract. Other access roads and fire lanes have been maintained to the extent possible under manpower limitations. To protect the catchment area, the general public is admitted to the reservoir area only over the controlled Administration Road, with its many outlooks.

The fire look-out tower on Quabbin Hill has been of great service to the Commission since its construction in 1940. Broadcasting service for two-way radio communication for police and fire patrol, and other maintenance work is operated from this station. The Metropolitan District Police have a branch office at the Administration Building, which was placed in operation immediately after our country's entry into World War II. This police unit patrols the reservoir area in cars equipped with two-way radio communication. Further to facilitate maintenance problems and to aid in fire and police protection, the Commission maintains three work boats: the Dana, Enfield, and Greenwich. These boats are used constantly during the summer months. A ramp and utility wharf for access at all reservoir levels have been constructed. At numerous points along

these highways, where especially fine views of Winsor Dam (Figure 3) or of Quabbin Reservoir are presented, parking strips have been constructed for the convenience of the passing motorist. One such space is available on Administration Road near the memorial to Frank E. Winsor, former Chief Engineer (Figure 4). This point commands a fine view of the Winsor Dam.

FIG. 3.—GENERAL VIEW OF WINSOR DAM LOOKING WEST.

WARE RIVER WATERSHED

The upper portion of the Ware River measured from the Coldbrook Intake Works covers an area of 96.8 sq. mi.

*Page 202, Line 7.** Diversions from the Ware River are made as permitted by War Department regulations. During the year 1944, the amount drawn was 12,573,900,000 gal. Of this volume, 11¼ billion gal. were diverted into Quabbin Reservoir and 1½ billion gal. into Wachusett Reservoir. The maximum day's diversion amounted to 1,505,500,000 gal. on June 25, 1944.

*Page and line numbers refer to the original paper in this Journal, Vol. 54 (1940).

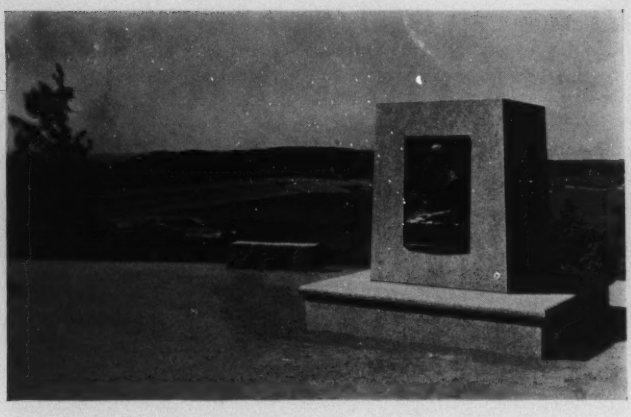

FIG. 4.—WINSOR MEMORIAL OVERLOOKING QUABBIN RESERVOIR.

Page 202, Line 31. The purchases in this watershed will total 21,797 acres or about 35% of the watershed

Page 202, Line 36. General takings covering land purchased in the Ware River Watershed made since the 1939 report total 16,590 acres (see Fig. 5).

Page 203, Line 2. Approximately 30 mi. of highway have been abandoned in the Ware Watershed area. Barriers are to be erected at the entrances to all abandoned roads through the Commonwealth's holdings.

RUTLAND-HOLDEN SEWER

Page 204, Line 27. This trunk sewer removes the sewage of the Rutland State Hospital and the U. S. Veterans' Hospital and was designed to permit connections by the towns of Holden and Rutland so as to eliminate as sources of pollution Holden Center, Jefferson Village, and Rutland Center and to divert the industrial wastes in Jefferson Village. The town of Holden has recently connected its new sewer system to this trunk sewer, and it is expected that the town of Rutland will do so this year. For the year ending November 30, 1944,

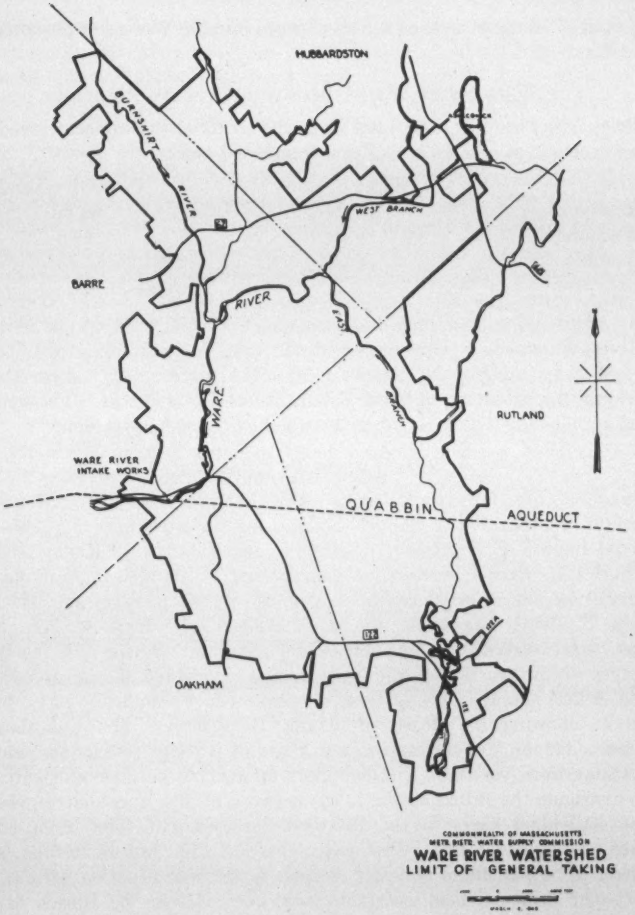
HUBBARDSTON
BARRE
RIVER
WARE
EAST BRANCH
WEST BRANCH
RUTLAND
WARE RIVER
INTAKE WORKS
QUABBIN
AQUEDUCT
OAKHAM
COMMONWEALTH OF MASSACHUSETTS
METR. DIST. WATER SUPPLY COMMISSION
WARE RIVER WATERSHED
LIMIT OF GENERAL TAKING

FIG. 5.

a total of 74 mg of sewage was discharged into the Worcester Sewerage System.

The Ware-Swift Watersheds and Quabbin Aqueduct

Page 205, Line 14. The total property acquired in both watersheds will amount to about 75% of their combined area.

	Water Surface	Protective Lands	
Reservoir	Sq Mi		Sq mi
Wachusett	6.46		5.86
Quabbin	38.60	Swift	87.7
		Ware	34.1

An additional taking No. S-30 was made on May 4, 1944, in the Swift River Watershed. This increased the total area in this region by 75.58 acres making the present total 75,241 acres. This alters the general taking shown on Real Estate Sheets 453 and 454. The new taking includes 3.1 mi of highway which will not be abandoned.

Real Estate Purchases

Page 205, Line 32—Organization. The Commissioners of the Metropolitan District Water Supply Commission on November 30, 1944, were Eugene C. Hultman, Chairman, and Edward J. Kelley and Charles H. Brown, Associate Commissioners. R. Nelson Molt has served as Secretary since the beginning of the project, and Harvey E. Weir has continued as conveyancer. Karl R. Kennison, who served as Assistant Chief Engineer during the early stages of the work and who had previously assisted in the preceding water supply investigations, became Chief Engineer early in 1939 following the death of Frank E. Winsor. His task has been a difficult one during the war years of priority restrictions and marking time, for there is still important work to be done efficiently to distribute the stored waters to the network of pipe lines that supply the individual users in the Metropolitan District. The proposed pressure aqueduct from Weston to Chestnut Hill and extensions is ready to be put under contract as soon as the war situation permits.

The principal field assistants have been Harold W. Horne, deceased, N. LeRoy Hammond, Richard R. Bradbury, William W.

Peabody, and Frederick W. Gow. They have served as Division Engineers. Mr. Hammond was in charge at Enfield until 1936. Mr. Horne directed the tunnel work until his death in 1928 when he was succeeded by Mr. Peabody. In 1936, Mr. Hammond resigned to assume a position with the New York Water Supply Board, and Mr. Peabody was placed in charge of all field offices, until the date of his retirement which became effective December 15, 1944. At this time Frederick W. Gow was placed in charge of all field offices as Division Engineer. The work performed under the direction of this Commission and its engineering force stands out as the last word in modern water supply engineering. There are no frills, emphasis having been placed on safety and dependability. The cost, as a whole, of the storage basins and the tunnel system west of Wachusett reached about 80% of the original estimate, a rare occurrence in these or any other days. The real estate costs have been low as comparisons will show.

The saving achieved, combined with PWA funds, has been used in the construction of a high-pressure aqueduct now completed to the Charles River at the Weston-Newton line.

Real Estate Costs

Page 217, Line 33. On November 30, 1944, the Metropolitan District Water Supply Commission had purchased 104,210 acres of land, with all buildings and rights, in the Swift River and Ware River watersheds, including the necessary rights-of-way for tunnel, highway, and trunk sewer purposes at a total cost of $10,307,638, or at the rate of $98.91 per acre. The total expenditure, including overhead charges and deducting revenues, amounted to a net cost of $11,614,749, or a unit cost of $111.46 per acre.

Total expenditures for the project including construction amounted to $50,328,744, the cost of real estate thus being about 22% of the entire cost.

No cost records appear to have been published since 1940 covering real estate acquired for water supply or flood control reservoirs, so it has not been possible to extend Table 7 of the original report which gives cost comparisons of real estate for water supply reservoirs. It has been revised, however, to show latest costs. The favorable balance has increased since 1939.

Cemetery

Page 229, Line 18. A total of 7,561 bodies have been removed from the 34 cemeteries formerly located within the Quabbin Reservoir watershed. Of these, 6,551 bodies were reinterred in Quabbin Park Cemetery, and 1,010 bodies were reinterred in other cemeteries, in accordance with the desires of nearest of kin. All removals from the reservoir area were completed on October 4, 1944.

Quabbin Park Cemetery

Page 233, Line 28. In January 1944, seven additional 8-grave lots were developed. Hence there are present provisions for 11,976 burials. Deducting therefrom 6,551 occupied graves leaves a total of 5,425 graves available for future burials.

A utility building has been constructed for the storage of necessary equipment and tools. In this building are kept all the former town cemetery records. The Commission's cemetery staff also has quarters within this building. A portico gives partial protection to some of the memorials removed from old cemeteries.

Page 239, Line 9. During the past year a maintenance force averaging four men has been employed at Quabbin Park Cemetery.

Page 234, Line 19. A total of 104.1 acres of land was taken for cemetery purposes of which 13.3 acres have been developed.

Page 237, Line 24. The rules and regulations governing Quabbin Park Cemetery were revised August 27, 1942, to increase the cost of monument foundations from $2.00 to $4.00. These rules were printed in the 1939 report, Pages 251 to 253.

Page 238, Line 21. Quabbin Park Cemetery Costs.

Purchases and Settlements	$ 8,850
Construction	91,476
Water Supply Systems	1,459
Maintenance	42,547
Miscellaneous Expenditures	134,596
	$278,928
Revenues	3,817
	$275,111

Page 238 Line 30. The cemetery work involved 7,561 removals from Quabbin Reservoir area of which 6,551 were removed to Quabbin Park Cemetery and 1,010 were moved to outside cemeteries plus 6 bodies from outside cemeteries and 258 new interments in Quabbin Park Cemetery (Figure 6) a total of 7,825 completed burials. The cost was $122,842.00, a unit cost of $16.00 per burial.

The removals to outside cemeteries cost about $31, while the unit cost of removals to Quabbin Park Cemetery was about $18 per body.

FIG. 6.—QUABBIN PARK CEMETERY

QUABBIN RESERVOIR

Quabbin Reservoir, barely mentioned in the 1939 report, has filled rapidly during the five-year period and has become the largest inland body of water in Massachusetts. On November 30, 1944, it held nearly 238 billion gallons of water, nearly 60% of its ultimate capacity of 415 billion gallons.

The reservoir level on that date, 506.5±, stood about 125 ft above the original river bed, with about 23.5 ft to go. A high level of

508.26 was attained on July 7, 1944, the later low level being the result of drafts in favor of Wachusett Reservoir.

The strategic intake at Coldbrook has been utilized to the greatest advantage by the diversion of floods in excess of 85 mgd. During the year 1944, about 25.42 billion gal. were drawn from Quabbin Reservoir for Wachusett Reservoir and Greater Boston's benefit.

The following table shows the distribution of storage in the various basins of Quabbin Reservoir.

	Elev. of Water Surface	Storage—mg Above the Ground	Estimated Ground Storage	Total Available
Between Lower Intake and Quabbin Reservoir Level	506.47	235,700	12,300	248,000
Additional:				
Behind East Branch Regulating Dam (above Elev. 516.0)	530.62	1,760	110	1,870
Behind Middle Branch Regulating Dam (above Elev. 512.0)	530.10	320	20	340
Total Available Storage Nov. 30, 1944		237,780*	12,430	250,210

This revision would not have been possible without the coöperation of the Commission's engineering forces. Assistant Civil Engineer Norman D. Hall has performed most of the necessary research and has supplied all required data. This assistance is gratefully acknowledged.

In order to complete the record there are included herewith:

a. A continuation of the "Taking Record" (page 211).
b. A revision of Table 3 (page 218).
c. A revision of Table 9 (page 228).
d. A revision of Table 10 (page 230).

*This is in addition to about 10,000 mg. below the sill of the lower intake, not available for draft to Wachusett Reservoir.

INCIDENTAL REVISIONS

Page 196, Line 18. Purchases in the Swift River Watershed, total 80,948 acres, or 68% of the watershed.

Page 202, Line 31. The purchases in this watershed will total 21,797 acres, or about 35% of the watershed.

Page 221, Page 5. A sample of the cost of buildings and lands, Swift River Watershed.

Page 224, Line 19. To date settlements for the Rutland-Holden Sewer have amounted to $32,279.00 or about $3,369.00 per mi, making the unit cost per acre about $1,463.00.

Page 227, Table 8. (This situation same as Table 7.)

TAKING RECORD
(*Continued from Page 212, Volume 54, 1940*)

Taking No.	Owner or Purpose	Town	County	Instrument Recorded Date	Book	Page	Plan No.	Plan Recorded Date	Book	Page
S-30	Nichewaug Area	Petersham	Worcester	May 4, 1944	2916	264	S-30	May 11, 1944	133	44
W-2	General Taking	Oakham, Rutland Barre	"	April 5, 1941	2810	365	W-2	March 27, 1941	117	14
W-3	" "	Hubbardston	"	April 28, 1944	2883	401	W-3	April 28, 1944	130	35
W-4	" "	Rutland	"	" " "	2883	407	W-4	" " "	130	36
W-5	Walter E. Clark	"	"	June 22, 1943	2888	461	W-5	June 22, 1943	130	64
W-6	General Taking Including Cross Property	"	"	April 28, 1944	2914	396	W-6	April 28, 1944	133	36

TABLE 3.—REAL ESTATE COSTS TO NOVEMBER 30, 1944

Section	Purchase & Settlements[a]	Direct Overhead[b]	Indirect Overhead[c]	Gross Cost	Revenues Sales & Rents	Net cost	Unit Cost Per Acre Purch. & Settle.	Unit Cost Based on Net cost
Swift River Watershed including Quabbin Park Cemetery (82,019 acres)	$8,389,628	$1,281,678	$585,181[d]	$10,256,467	$1,045,137	$ 9,211,330	$103.64	$113.79
Ware River Watershed including Rutland-Holden Sewer (21,120 acres)	1,762,403	421,815	part f 59,467*	2,243.685	40,000	2,203,685	83.45	104.34
Quabbin Aqueduct (1,071 acres)	149,607	49,417	4,690*	203,714	10,000	193,714	139.69	180.87
Total Project (104,210 acres)	10,307,638	1,752,910	d, e & f 649,338	12,709,886	1,095,137	11,614,749	98.91	111.46
Coldbrook-Swift Section of Quabbin Aqueduct (518 ac.)	26,260	9,941	719*	36,920	None	36,920	50.69	71.27
Wachusett-Coldbrook Section of Quabbin Aqueduct (553 ac.)	123,347	39,476	part f 3,971	166,794	10,000	156,794	223.05	283.53
Swift River Watershed and Quabbin Aqueduct (83,090 ac.)	8,539,235	1,331,095	d, e, part f 589,871	10,460,201	1,055,137	9,405,064	102.77	113.19
Ware River Watershed and Wachusett-Coldbrook Section (21,673 acres)	1,788,663	461,291	63,438	2,313,392	50,000	2,263,392	82.53	104.43

[a]Includes awards by Court Decree—Jury and Board of Referees.
[b]Includes legal, expert and trial expense, taxes, maintenance, fire and police protection, rental expense, etc.
[c]Includes percentage of field engineering and general overhead charges as noted by d, e and f.
[d]49% of total general overhead and engineering charges.
[e]0.5% of total general overhead and engineering charges.
[f]10.8% of total general overhead and engineering charges.
*Estimated proportion of $46,900.

TABLE 9.—AMOUNTS PAID IN LIEU OF TAXES AND FOR TAXES—QUABBIN RESERVOIR AREA AND WARE RIVER WATERSHED AREA

Yearly Totals			Details for Year 1944			
Year	Total Tax	Town	Valuation Basis	Rate	Amounts Paid	Total
1927	$ 1,764.51	Barre	$ 97,370.00 in lieu	$37.00	$3,602.69	$3,602.69
1928[a]	11,574.75	Belchertown	7,150.00 tax	39.00	278.85	
			29,030.00 in lieu		1,132.17	1,411.02
1929	20,697.61	Framingham	13,309.50 in lieu	30.80	409.93	409.93
1930	29,625.49	Hardwick	58,602.00 in lieu	40.00	2,344.08	2,344.08
1931	39,204.50	Holden	7,378.00 in lieu	32.00	236.10	236.10
1932	42,838.83	Hubbardston	1,135.00 tax	34.60	39.27	
			in lieu			
1933	49,301.11	Marlborough	40.00 in lieu	37.50	1.50	1.50
1934	60,750.49	Natick	1,150.00 in lieu	32.80	37.72	37.72
1935	53,131.72	New Salem	5,750.00 tax	32.80	188.60	
			210,509.36 in lieu		6,904.71	7,093.31
1936	55,010.38	Newton	8,000.00 in lieu	26.80	214.40	214.40
1937	62,743.07	Oakham	1,000.00 tax	27.50	27.50	
			56,905.00 in lieu		1,564.89	1.592.39
1938[b]	27,888.01	Orange	380.00 in lieu	38.60	14.67	14.67
1939	28,623.71	Pelham	2,692.00 tax	24.00	64.61	
			87,483.00 in lieu		2,099.59	2,164.20
1940	29,121.84	Petersham	9,450.00 tax	26.40	249.48	
			21,488.00 in lieu		567.28	816.76
1941	31,195.96	Phillipston	800.00 in lieu	44.00	35.20	35.20
1942	34,324.29	Princeton	8,605.00 in lieu	34.40	296.01	296.01
1943	33,494.06	Rutland	1,835.00 tax	27.40	50.28	
			144,479.89 in lieu		3,958.75	4,009.03
1944	33,051.07	Shutesbury	64,850.00 in lieu	24.00	1,556.40	1,556.40
Total to Date	$644,341.40	Southborough	2,983.00 in lieu	31.00	92.47	92.47
		Ware	2,930.00 tax	36.00	105.48	
			12,520.00 in lieu		450.72	556.20
		Wayland	40,133.50 in lieu	29.00	1,163.87	1,163.87
		Wendell	2,210.00 in lieu	36.00	79.56	79.56
		Westminster	350.00 in lieu	34.00	11.90	11.90
		Weston	64,967.69 in lieu	21.00	1,364.32	1,364.32
						$29,103.73

aPrescott omitted 1928 and all following years.
bDana, Enfield, and Greenwich omitted.

TABLE 10.—DISCONTINUED CEMETERIES IN VICINITY OF QUABBIN RESERVOIR

Cemetery	Location Original Town		Classification	No. of Lots	Approx. No. of Burials	Original Amounts Perpetual Care Funds	Area Acres
Bacon	Belchertown		Family	1	4	——	0.06
Blue Meadow	Belchertown		Neighborhood	1	15	——	0.20
Brown's	Dana	(1)	Family	38	124	$ 350	1.30
Brown's Evergreen	Dana	(1)	Family	14	68	——	0.36
*Cemetery Hill	Enfield	(2)	Association	60	254	2,225	1.29
*Church	Enfield	(2)	Public	257	853	1,850	1.39
Dana Center	Dana	(1)	Public	191	714	2,150	2.30
*Demars, Frank	Dana	(1)	Family	1	1	——	0.01
Fish Hill	Prescott	(2)	Public	76	235	175	0.9
Golden Lake	New Salem		Public	41	219	600	0.52
*Greenwich	Greenwich	(1)	Public	504	1,680	3,832.65	4.00
Hamilton	Shutesbury		Family	6	9	——	0.05
Hopkins	Dana	(1)	Neighborhood	11	36	——	0.10
Howe	Enfield	(3)	Family	1	18	——	0.40
*Linzie, Isaac	Prescott	(2)	Neighborhood	24	59	——	0.15
*Loomis	Dana	(1)	Family	1	1	——	0.01
*Ludlow Mfgs. Assn.	Enfield	(4)	Family	1	1	——	0.01
Mann, Thomas S.[a]	Prescott	(2)	Family	1	8	——	0.01
*Old North Dana	Dana	(1)	Neighborhood	19	43	——	0.40
Packardsville	Enfield	(4)	Public	80	209	300	0.43
Packardsville Church	Enfield	(4)	Church Assoc.	7	22	——	0.06
*Pelham Hollow	Prescott	(2)	Public	187	738	300	1.6
*Pine Grove	Dana	(1)	Public	264	574	2,230	4.6
Pine Grove	Prescott	(2)	Association	90	170	917.52	1.3
*Powers, Jason	Prescott	(2)	Public	22	51	——	0.3
Richardson	Dana	(1)	Neighborhood	6	15	——	0.44
Shaker	Petersham		Family	1	13	——	0.07
Snow	Petersham		Public	37	151	100	1.4
Stone	Dana	(1)	Neighborhood	14	41	——	0.32
*Town	Dana	(1)	Family	8	20	——	0.26
Town House	Prescott	(2)	Public	61	208	450	0.71
Wilder	Enfield	(2)	Family	1	2	——	0.01
Williams	Dana	(1)	Neighborhood	17	55	——	0.11
*Woodlawn	Enfield	(2)	Public	376	949	1,825	3.68
Stevens, A. Albert	Greenwich	(1)	Family	1	1	——	0.01
				2,419	7,561	17,305.17	28.40

*Below flow line of Quabbin Reservoir.
[a]Sometimes called Brown's Cemetery.
(1) Now Petersham. (2) Now New Salem. (3 Now Ware. (4) Now Pelham.

SUBMARINE PIPE LINES IN DEEP WATER AT PORTLAND, ME.

BY JAMES R. GARDNER*

[*Read September 21, 1945.*]

Early in 1942, one of the urgent needs developed by the war emergency was an adequate and reliable water supply to defense installations located on islands in Portland Harbor. Investigations of ground water supply at various times and places revealed that the ground water was of poor quality and inadequate in quantity, and it was evident that new pipe lines would be required to augment the existing over-taxed lines of the Portland Water District to several of the islands. This involved difficult installation of subaqueous mains, in some places 120 ft deep, which is believed to be a record depth for such construction.

This urgent need for water facilities resulted in a substantial allotment of Government funds to finance and construct a project, the scope of which was to extend the Portland Water District lines from the mainland at Martin's Point, by land and subaqueous pipe to Mackworth Island, Great Diamond Island, Long Island, Peaks Island and House Island. This required 24,000 ft of subaqueous mains and 12,000 ft of land pipe to supply the acute military needs in addition to civilian requirements.

Speed of installation being the most important consideration on all operations, the work had to be done with such materials and equipment as were available, accepting the hazards of construction work exposed to the open ocean and swift tidal currents, during a winter of record-breaking severity. Harbor regulations limiting the work to certain daylight hours and providing clear navigation channels in a busy habor, together with acute labor shortage, added difficulties in making the scheduled progress.

The selection of pipe presented a major problem on account of W.P.B. restrictions on such critical material. Cast iron pipe, which

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is most desirable for this work could not be obtained for 6 months and such delay was prohibitive. Therefore 12-in. wrought iron pipe was selected because it was readily obtainable locally and practical for use in water depths to 40 ft which were encountered in the most emergent portions of the work.

Five separate submarine pipe line installations were included in the project: Two sections totaling 9,600 ft were built of 12-in. wrought iron pipe; three sections totaling 8,900 ft were built of 8-in. cast iron pipe when available; a temporary emergency line 4,500 ft long was built of used 3½-in. steel boiler tubing. Cast iron pipe for the land lines was supplied from Portland Water District surplus.

In order to protect the pipe against freezing and other damage, all submarine pipe was buried in trench to a minimum depth of 5 ft. In one section it was necessary to construct a trench 15 ft deep for a distance of 2,000 ft in order to clear deep harbor navigation under consideration.

Wrought Iron Pipe. It was first necessary to erect a gridiron, or platform, of heavy timbers, readily accessible along the shore for the pipe assembly, and convenient for launching the pipe sections at high tide. The pipe was delivered to the site in 20 ft pieces with beveled ends; ten of these lengths were welded together to form 200-ft sections, a practical length for ready handling. See Figure 1.

As shown in Figure 2 each welded joint was reinforced with a sleeve 18 in. long covering the joint and fillet welded to the pipe. Slip-on forged flanges were welded to each end. A ¼-in. tap was made in each sleeve and the joints tested by air at a pressure of 150 psi in the space between the sleeve and the pipe. This tested both the butt and fillet welds. The sleeve was then sealed by a ¼-in. plug. Specimens of welds were taken periodically and tested in the Thompson & Lichtner laboratories.

Following the testing, the pipe was coated on the outside with heavy "No-Oxid" grease and wrapped by hand with heavy bituminous impregnated paper to retard corrosion due to salt water. Finally the ends of the 200-ft. sections were sealed by bolting blind flanges to the end flanges. This made the pipe sections buoyant and easily towed to the desired site by a small towboat.

To provide a guide for the trench excavation and pipe installa-

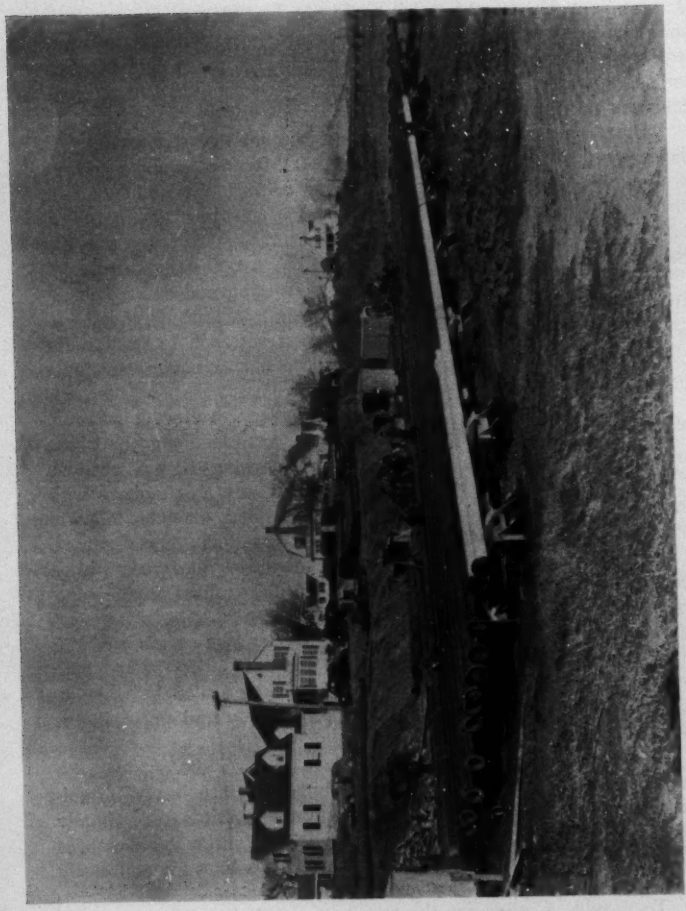


FIG. 1.—LAUNCHING PLATFORM FOR WROUGHT IRON PIPE.

The illustrations that accompany this paper are presented through the courtesy of Engineering *News-Record*.

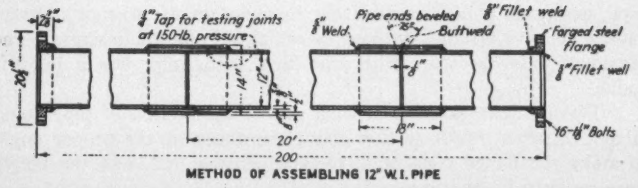


FIG. 2.

tion, dolphins consisting of three timber piles each, were driven on 150-ft centers parallel to, and a few feet from the center line of the pipe. These dolphins extended along the entire line from Mackworth Island to Gt. Diamond Island, approximately 7,100 ft with exception of an adequate opening for navigation. This provided alignment and allowed the work to proceed in frequent fog and haze without depending on shore targets for alignment.

The marine equipment consisted of three steam derrick lighters equipped for dredging with 1 cubic yard clam shell buckets. This equipment was utilized for excavating the trench and laying the pipe, being held in alignment by means of heavy anchors and lines to the dolphins.

Laying operations closely followed the trenching and were begun at the shore in shoal water where 600 ft of pipe was installed in one section. This was floated into position over the trench and sunk by introducing water at the shore end. No support was needed excepting a raft to keep the foreward end above water which was approximately 10 ft in depth.

This method was satisfactory in shallow water, but, in deeper water, the problem was to prevent overstressing that portion of the pipe extending from the bottom of the trench to the surface as more pipe was added. This was accomplished by a method initiated on this job called "controlled buoyancy" originated by Raymond F. Bennett, the Contractor. This method consisted of supporting, by buoys, the long section of vertically curved pipe of some 300 to 400 ft reaching from the raft on the forward end to the bottom of the trench. The buoys were spaced 65 to 70 ft apart and caused the

pipe, acting as a beam, effectively to maintain a curve of uniform radius, concave upward, without exceeding the allowable stress. The maximum safe curvature with pipe filled with water was a 1,250-ft radius.

Two derricks working at each end of the section of pipe being added, raised a 200-ft section above the water at the proper angle to make the flange connection to pipe already laid, and the buoys were connected. See Figure 3.

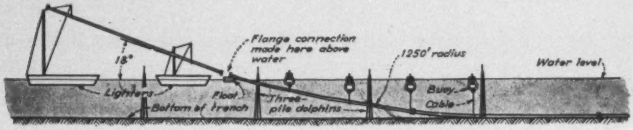
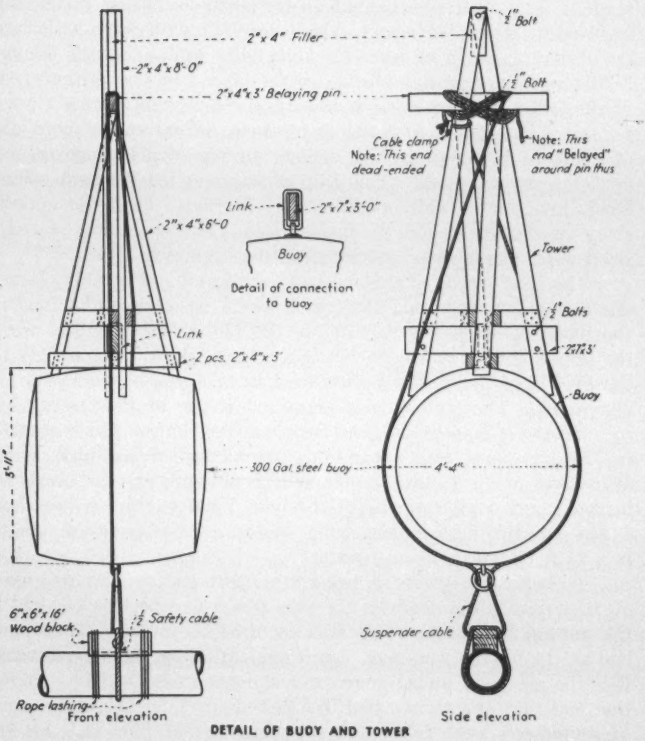


FIG. 3.—LAYING PIPE BY CONTROLLED BUOYANCY.

The buoys are shown in Figure 4. They consisted of 300-gallon steel mine net floats borrowed from the U. S. Coast Guard, each having a maximum lifting power of 2,800 lbs when submerged. These were especially adaptable for use in this work when surmounted by a timber quadrupod fitted with a belaying pin near the top. A ½-in. suspender cable was "dead ended" at the pin, extended down one side of the barrel and through a link on the bottom of the barrel, thence through an eye in a wood block attached to the pipe; next, upward through the link on the bottom of the barrel and finally up the opposite side of the drum to the belaying pin. This rigging held the quadrupod vertical and permitted adjustment of the suspender above water after the buoy became submerged. A lanyard connected the buoys to prevent spinning.

The laying procedure followed was to move the raft forward as new sections of the pipe were added and buoys attached. The buoys alone did not support the total weight of the filled pipe by a considerable margin, and removal of the raft supporting the forward end would allow the pipe to sink. Thus, lowering of the pipe was effected by moving the raft forward.

As the work advanced and the pipe at the rear reached the bottom, the rear buoy was released and moved forward and re-used.



DETAIL OF BUOY AND TOWER

FIG. 4.

In following this method, it was of utmost importance that the suspenders attached to the buoys should be progressively slackened away so that the belaying pins would not become submerged. During the slackening process, the outside turn of the suspender cable on the belaying pin was loosened slightly to allow other turns to

render. This operation caused an irregular slackening motion and involved considerable impact, which, together with wave action and the currents, tended to cause the suspenders to cut through the eyes of the wood attachment blocks on the pipe. In one instance, two blocks failed in quick succession causing the pipe to rupture close to a flange connection. As a safety measure, a "preventer," consisting of a loop of wire rope passing around the pipe and through the suspender bight was used. This loop of wire carried the load when a block gave way. This operation was continued until the opposite shore was reached where the final section, 700 ft long, was placed in shoal water in the same manner as at the beginning.

The chief merits of this method were speed and economy largely due to the assurance that the trench would be occupied by the pipe shortly after being dug and before the filling in by natural wash; the use of submarine divers for laying the pipe was eliminated; the use of a large bulky chute often used in this type of work was also eliminated. The method also permitted re-use of the buoys.

Repairing Ruptured Pipe. Repair of the rupture which occurred in this pipe line, was made upon completion of the pipe laying. Water was pumped into the pipe at high pressure and the break was located about at the middle of the line, 3,500 ft from either shore. It was indicated by turbulent muddy water. At this point the pipe lay in a 15 ft trench in 40 ft of water.

To begin the repairs, it was necessary to excavate an area about 50 ft square to the depth of the pipe which had become covered by the natural backwash. This was required to provide ample space and safety for the workman. An examination by the diver revealed that the pipe had pulled apart several inches near a flange connection and that one section had dropped about 5 in. below the other. Measurements were taken and the alignment of pipe on each side of the break obtained by means of templates. It was then possible accurately to reproduce these actual conditions in the Portland Water District Shop by means of a model made of similar sized pipe. A split flanged sleeve of cast iron was made to fit this model, covering the pipe and flanges near the break. This split sleeve was flanged for bolting together, and each end was hubbed for caulking with lead. The sleeve was installed on the model, leaded, and caulked. It

was then removed from the model and taken to the site of the work and a diver placed it over the broken pipe in 40 ft of water. After bolting the sleeve firmly in place and recaulking, later tests of the line showed that an excellent permanent repair had been made.

A shorter line of the same type of pipe was constructed across a tidal estuary by an uncommon method. In building this line, the construction procedure had to provide for future deepening of a navigation channel, as shown in Figure 5. This problem was solved

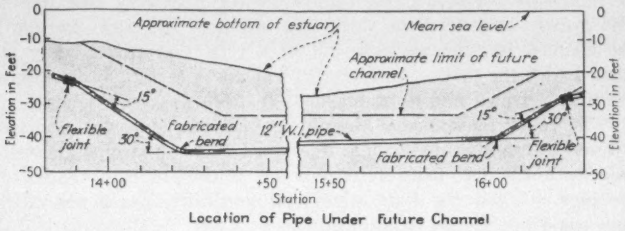


FIG. 5.

by constructing on shore a "U" section about 250 ft in length with fabricated bends at the bottom of the "U" and a combination of fabricated bends and cast iron ball joints at the upper ends of the "A". See Figure 6. The ball joints were protected against over-

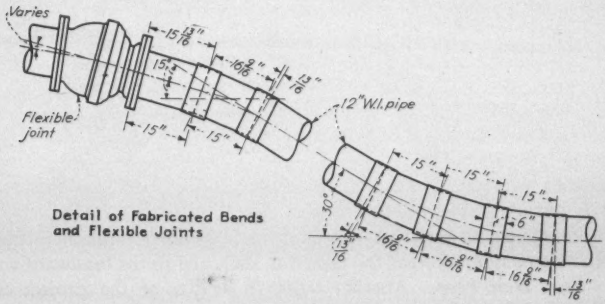


FIG. 6.

stress by means of timber strongbacks that limited the movement of the joint. These strongbacks were left in place. When completed the "U" was floated into place. At slack tide it was filled with water while being supported at each end by a lighter. The ends were held above water level until the section was joined by bolted connections to the adjoining pipe.

At the channel location, tidal conditions were severe, and at low water the available working space was limited by the presence of tidal flats. Floating ice, formed by the extremely cold weather also greatly hampered the work. In addition, the ocean bottom at the channel location was soft silt of a type that caved badly and shifted with the tides. As a result of all these factors, excavation of the trench, which had to be made 25 ft deep, was very difficult.

To check the grade of the pipe, which was almost immediately covered by washed-in silt, light lines were tied to the pipe at several points. These lines had reference points at the proper distance from the pipe. When the lines were held vertically, the grade of the pipe could quickly be determined.

At each end of the two water crossings just described, expansion joints were provided. Each joint, as shown in Figure 7, was housed

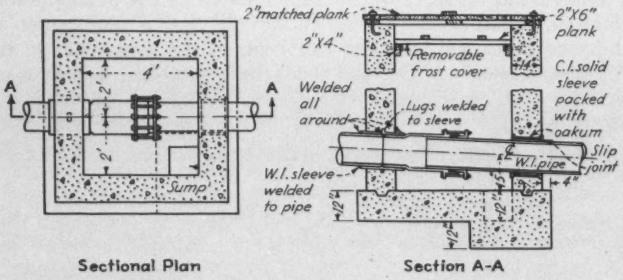


FIG. 7.—EXPANSION JOINTS AT ENDS OF WROUGHT IRON PIPE CROSSINGS.

in a concrete chamber. A slip-joint was provided through the wall on the water side, whereas the pipe was anchored to the landward wall.

Cast Iron Pipe. Another 9,000-ft section of the project was

started when it was possible to procure 8-in. and 12-in. heavy-duty cast iron flexible-joint pipe which made installation possible in depths of 120 ft. The chief concern was dredging a 5-ft trench followed closely by the pipe laying, and caring for a dozen submarine communication cables while battling the weather of the open ocean and severe undertow currents.

The first operation was a thorough exploration of the bottom with divers in which the diver worked almost entirely by the sense of touch, locating and marking the submarine cables that were widely scattered. To supplement this exploration, the bottom was dragged by an extra-heavy grapnel penetrating several feet into the muddy bottom.

To dredge the trench, a caterpillar crane capable of handling a 1½ cu yd clam shell bucket, worked from a scow 110 ft long and 30 ft wide. The scow was moored quarterly by means of ¾-in. cables about 600 ft long attached to 6-ton mooring stones. See Figure 8.

FIG. 8.—TRENCHING SCOW.

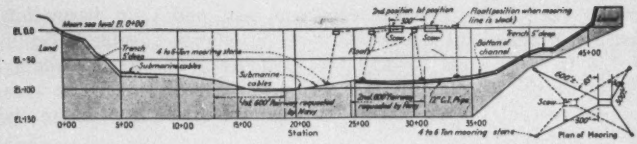


FIG. 9.—METHOD OF LAYING CAST IRON PIPE.

These moorings, as shown in Figure 9, were attached by 1-in. cable to substantial floats 24 in. by 24 in. by 14 ft made up of 12 in. by 12 in. spruce bolted together, with an eye being formed by the cable, so that connection to the mooring lines from the scow could be readily made above water. The scow was placed and held in position and alignment by adjusting the length of the mooring cables by means of two double-drum deck engines, alignment being obtained from targets on the shore. In the deep dredging, an ingenious apparatus was devised for keeping the bucket in line and preventing twisting. This consisted of an old 1,500-lb steam pile hammer suspended in vertical guides on a set of double blocks and tackle providing a movement of about 10 ft, and erected on the rear of the scow. The lead-line ran underneath the scow to the bucket and was kept clear of the bottom of the boat by roller guides mounted in a frame so pivoted that it could be swung clear of the bottom of the boat when not in use. The excavated material was raised about 10 ft and swung 20 ft clear of the trench. This was found to be far enough to keep back-wash to a minimum and yet keep the material handy for backfilling.

After about 300 ft of trench were excavated, the barge was moved back and the pipe laid in this excavated section. It was then necessary to shift the mooring anchors ahead 300 ft to permit the work to continue.

The pipe came in 12-ft lengths and was assembled on the deck in 60-ft sections for ready handling. A strong-back 60 ft long, adequate for a section, and supporting each length of pipe was used to lower the pipe into the trench. The strong-back consisted of a 60-ft steel beam, made up of 8-in channels back to back about 4 in. apart. As shown in Figure 10, it was equipped with chains spaced

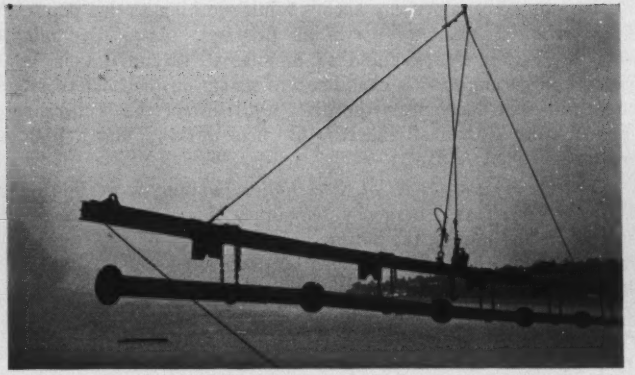


FIG. 10.—STRONG-BACK HANDLING OF 60 FEET OF CAST IRON PIPE.

at 12-ft intervals for supporting each length of pipe between the flexible joints. The chains were fixed to the strong-back at one end, looped about the pipe, and hooked into a V-shaped slot in an ear welded to the strong-back. By this arrangement, the strong-back could be readily cut loose from the pipe after it had been laid. The pipe was lowered into place and flange connections were made by the diver on the bottom. To guide the pipe into position to be connected to the section already placed, the whip-line of the crane was attached to the free end of the pipe already placed close to the flange and held taut. A short chain was passed around the spigot end of the pipe being lowered, and looped around the whip-line. This guided the spigot end to within several feet of the bell end. From this position, the diver could readily maneuver the pipe into final position and bolt it together. After making the joint, the whip-line was shifted to the forward end of the pipe just added in order to aid in laying the next 60-ft section.

In general, working in depths of 100 feet or more, progress was limited to laying 120 ft of pipe daily, weather permitting. This required making two joints and was accomplished by using two divers

making one descent per day each. While working at this depth, the divers required about 45 psi of air pressure. About five minutes were required to descend and 45 minutes to ascend. As a safety measure, a decompression chamber was set up on the boat to recompress and then decompress the diver and prevent the occurrence of "bends"—an occasional affliction of men working under high air pressures.

Emergency Line Built of Steel Boiler Tubing. A portion of the project required an emergency temporary line 4,500 ft long from island to island laid on the bottom in water depths of 120 ft. A wartime expedient was again employed by procuring second-hand 3½-in. steel boiler tubing, the only material available on short notice. This came in convenient lengths and was assembled into readily handled section of 350 ft by welding. A short sleeve fitting the pipe snugly and adapted for a Victaulic 2-bolt coupling was welded to each end of the section. See Figure 11. A 5,000-ft length of ¾-in. cable was stretched across the channel and allowed to sink. The rear end was attached to the pipe and the forward end to a 10-ton caterpillar tractor which pulled the pipe across the channel. As the pipe was prepared in 350-ft sections, this amount was payed out and pulling

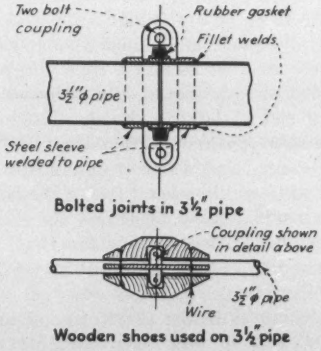


FIG. 11.

ceased until another 350-ft section was coupled together. It took about two days to pull the pipe across the channel. However, a month was consumed in erecting a long platform for welding and painting the pipe and making preparations.

As submarine communication cables resting on the bottom existed in the area crossed, it was necessary fully to protect these and place the pipe underneath the cables. To accomplish this, the pipe was first drawn over the cables which had been bunched together and securely bound. As shown in Figure 11, the pipe couplings had been covered by wooden shoes to protect the cables. Then, the pipe was cut with a hack saw by the diver, near each bunch of cables, and the cables were placed above the pipe. The ends of the pipe were then joined together by means of Dresser couplings. This line operated satisfactorily until the permanent 8-in. line could be installed.

The total cost of all work on the project was $800,000. The cost of the submarine portions of the work herein described was approximately $540,000. Unit costs of the several types of submarine pipe installed were as follows:

		Cost per ft
(1)	12-in. wrought iron pipe (unlined)	$21.00
(2)	12-in. cast iron pipe (Usiflex heavy duty)	37.00
(3)	8-in. cast iron pipe (Usiflex heavy duty)	35.00
(4)	3½-in. steel pipe (boiler tubing)	4.00

Unit costs for lines (1) and (4) are based on a cost plus-a-fixed fee contract in which the unit costs include all construction overhead. Unit costs for lines (2) and (3) are based on unit price contracts. The engineering fee is not included in any of these unit costs.

Metcalf & Eddy, Boston, Mass., were the consultants on this work. Harry L. Kinsel was in charge of design. E. B. Cobb was resident engineer during the early stages, and Neil A. Medbery engineer during the latter part of the work. Harry U. Fuller is chief engineer of the Portland Water District, which is supplying the water. Construction operations were carried on by four contracts with the following firms: Bennett Contracting Corporation, Portland, Me.; George M. Bryne, Boston, Mass.; Spearin, Preston & Burrows,

New York, N. Y., and Wyman & Simpson, Augusta, Me. The projects were financed and supervised by the Federal Works Agency and the writer, as Project Engineer, was in direct charge.

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CORROSION OF COPPER AND COPPER-BASE ALLOYS IN FRESH WATER

BY C. L. BULOW*

[*Read March 15, 1945.*]

Calcium Carbonate scale.—The dissolved salts found in fresh waters vary considerably in their influence on the corrosion rate of copper-base alloys. It has been known for a long time that certain waters when heated, will deposit thin to thick mineral scales on the metal surfaces with which these waters come into contact. The chemical composition of these mineral scales varies considerably. The most common scale found in water-heating coils, condenser tubes, and heat-exchanger tubes consists essentially of calcium carbonate ($CaCO_3$) which is generally formed by the breakup of calcium bicarbonate $Ca(HCO_3)_2$ at elevated temperatures according to the reaction: $Ca(HCO_3)_2 \rightleftharpoons CaCO_3 + H_2O + CO_2$.

Since the calcium carbonate that forms is much less soluble than the original calcium bicarbonate, it slowly precipitates and, over a period of time, builds up a white, yellow, or gray colored mineral scale on the metal surface. Frequently, when this reaction occurs, considerable stifling of corrosion takes place. Specimens of copper-base alloys have been examined that were so well protected by carbonate or silicate scales ranging from 0.005 up to 0.020 in. in thickness that they have resisted corrosion for generations.

Langlier's Saturation pH. W. F. Langlier's $CaCO_3$ saturation index sometimes is very helpful in determining the possible behavior of a water. The pH saturation (pH_s) can be defined as the pH that a water must have in order to deposit a calcium carbonate scale at a given temperature. The algebraic difference between the actual pH and the calculated pH_s is called the "calcium carbonate saturation index": $pH - pH_s = CaCO_3$ saturation index. This index gives a dependable indication of the probable behavior of a fresh water when it passes through a pipe or condenser tube, in so far as

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the tendency towards calcium carbonate scale deposition is concerned. This value also, within limits, gives some information concerning the corrosiveness of the water. A water with a pH_s less than the actual pH (a plus sign preceding the calcium carbonate saturation index indicates calcium carbonate over-saturation) will slowly deposit some of its mineral matter when it comes into contact with metals. If the pH_s is higher than the actual pH (a minus sign preceding the calcium carbonate saturation index indicates calcium carbonate under-saturation), the water will not form a calcium carbonate deposit on metal surfaces, and may even dissolve any pre-existing calcium carbonate deposit. In addition, this water may even dissolve metal corrosion products. It is for this reason that the non-scale-forming waters are generally more troublesome from the standpoint of corrosion than the scale-forming waters.

Since the actual pH and pH_s are associated with the total concentration of carbon dioxide, dissolved solids, alkalinity, and calcium ions, the actual pH may be brought up to the pH_s by several methods (familiar to the water works chemist) for reducing the carbon dioxide content, or by increasing the calcium content of the water.

Figure 1, originally published by John R. Baylis (1), shows a typical calcium carbonate equilibrium curve. This curve is not representative of all waters. Variations in the concentration of other salts would move the curve up or down as the case may be.

Silicate and Sulfate Scales. The calcium carbonate saturation index cannot be expected to predict the formation of other types of protective scales that may form, such as silicate or calcium sulfate scales. At the present time, the author is not aware of the existence of any formulas similar to Langlier's that would make it possible accurately to predict whether or not a water would form any of the other types of scales. However, much experimental work by water chemists has shown that certain types of water treatment may very effectively lower the corrosion rate of the metal by the formation of a protective scale or film.

Pollution and Bacteria. It is evident from the information availon the subject of water composition that waters vary within wide limits in the kind and quantities of bacterial food substances they carry. Consequently, the extent and variety of bacteria that flourish

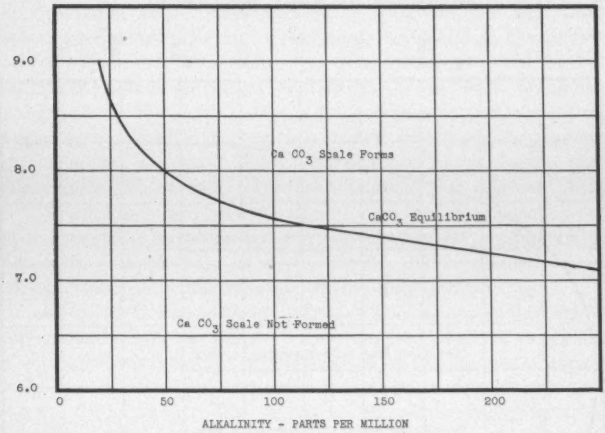

FIG. 1.—SOLUBILITY EQUILIBRIUM FOR CALCIUM CARBONATE.

in water pipes also vary considerably. Most of the bacteria that inhabit water pipes are attached forms that build incrusting colonies or slimes over the walls of the pipe. It has been found that these pipe-dwelling organisms may contribute towards increased corrosion of ferrous pipes with the production of tubercles and may give rise to "red-water" or bad odors.

Bacteria are capable of producing a number of acid corrosive substances both as by-products resulting from the break-up of their food and as the end result of cellular respiration. Accumulation of these acidic materials next to the tube or pipe wall beneath a bacterial slime may lead to a lowering of the pH in this area and consequently increase the corrosion rate. Several of the most troublesome materials formed by bacterial action are carbonic acid, hydrogen sulfide, sulfuric acid and elementary sulfur (2). Figure 2 indicates what may be expected when the pH of a water drops.

The information available concerning the action of bacteria on ferrous materials is more extensive than that available in connection

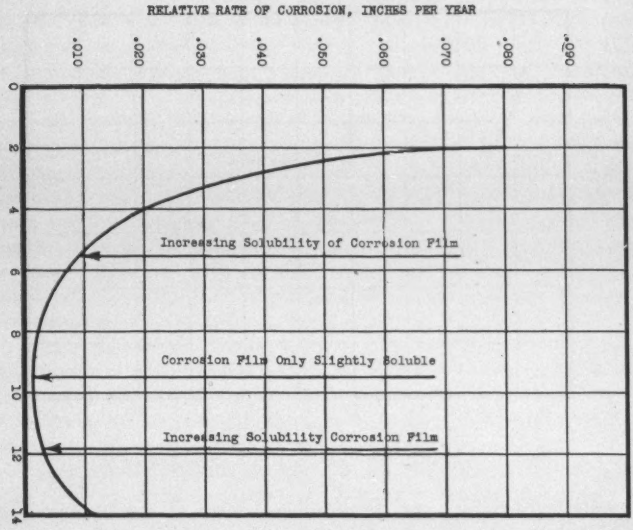

FIG. 2.—INFLUENCE OF pH ON CORROSION.

with the non-ferrous materials. Recently Cyril K. Calvert (3) published the results of some experimental work done on sections of 6-in. ferrous and non-ferrous lines. He concluded that "a more offensive dead-end odor developed in ferrous than in non-ferrous lines" and "multiplication of bacteria occurs in both ferrous and non-ferrous lines but to a lesser extent in the non-ferrous line". Further, the water from the ferrous pipe generally had a tarry odor intensified by prolonged storage in the pipes. The water in a copper-base alloy pipe never developed that odor, even after more than a year of storage in the line. "It is believed that this odor is of bacterial origin and is formed only in the presence of iron and sulfur in some form". His experiences indicated that it appeared reasonable to suggest the use of a copper or a copper-base alloy pipe lining to improve the odor and lower the bacterial count.

Ammonia and chlorine, added to water to kill algae and the disease-producing bacteria, are definitely beneficial to the community served. However, it appears that the dosage required to kill the incrusting colonies or slimes of bacteria on the walls of piping and tubing usually is so high that it may become objectionable for domestic purposes. While the corrosion of steel pipe lines can be overcome by the use of a cement lining, the problem of combating bacterial slimes may still remain. In this connection, it appears that both the corrosion problem and the slime-forming problem can be reduced to a considerable extent by the use of a thin non-ferrous lining. Non-ferrous lined or covered steel tubes and pipes have been used for years in the chemical and petroleum industries.

Effect of Composition of Alloys. The non-scale-forming waters may induce corrosion failures; for example, localized dezincification or general dezincification of the brasses of low copper content, such as Muntz metal (60% copper, 40% zinc) and yellow brass (67% copper, 33% zinc). This is more frequently encountered in hot water lines than in cold water lines. On the other hand, the higher copper alloys, such as red brass (85% copper, 15% zinc) copper, and the cast high-tin bronzes resist the corrosive action of such waters very well. This explains their wide-spread use in the form of piping and tubing. When the carbon dioxide content of the water is high, the coating of these high-copper alloys with tin gives considerable added protection and aids in the prevention of "green-water." Removal of the aggressive carbon dioxide is also effective.

Those materials that are susceptible to dezincification, such as Muntz metal and yellow brass, have been modified by the addition of 0.02 up to 0.2% of arsenic. This has reduced or practically eliminated dezincification and has lowered the overall corrosion rate to about one-third (or possibly less) that of the non-inhibited Muntz metal. Arsenical Muntz metal has been in use for quite a few years in industrial plants where fresh water is used. This alloy has not been widely used in domestic water distribution systems; this is also true of other copper-base alloys such as Admiralty metal, aluminum brass, aluminum bronze and 70-30 cupro-nickel which are extensively used in the form of tubing in heat exchangers in all industries. Because of the good corrosion resistance of these modified brasses to

fresh waters, we can expect more extensive use of these materials in the future.

Galvanic Corrosion. Generally, the coupling of copper-base alloys to one another does not lead to a significant increase in corrosion rate. The problem usually is one concerning the galvanic coupling of a copper alloy with a less noble metal, such as aluminum, steel, zinc, and other metals. The seriousness of a galvanic couple depends, in addition to the potential difference existing between two dissimilar metals, upon the electrical resistivity of the corrosive water, the scale-forming character of the water, the relative size of the exposed areas of the metals involved, and the actual current flowing between the two or more parts of the galvanic cell. Since the resistivity of fresh water is quite high, galvanic corrosion is usually localized quite near to or at the junction of the two dissimilar metals. In sea water, which has a much lower resistivity than fresh water, deep pitting due to the galvanic effect may occur some distance away from the point of actual electrical contact.

Effects of Size of Cathodic Area. Copper coupled to iron in water behaves as the cathode and the iron as the anode. The anodic reaction may be represented as:

$$Fe \rightarrow Fe^{++} + 2e$$

and the reaction occurring on the cathodic surface as:

$$2H^{+} + 2e \rightarrow 2H^{\circ}$$

$$2H^{\circ} + \tfrac{1}{2} O_2 \rightarrow H_2O$$

The latter reaction suggests that the oxygen supplied is an important factor and that the rate of corrosion depends upon the relative size of the anodic and cathodic surfaces in contact with the water; that is, the total oxygen pick-up from the solution depends upon the size of the cathodic area. This appears to be confirmed by numerous investigations which indicate that the larger the cathodic area, the more intense is the rate of corrosion of the anodic material. Apparently, the effect of the galvanic couple consists essentially of increasing or localizing corrosion which, in a given corrosive environment, would have occurred whether the dissimilar metals were connected or not. If the dissimilar metals are not in contact, then the development of localized areas of corrosion is largely a matter of chance depending upon other factors.

A large area of a less noble metal in contact with a small area of a copper-base alloy will have about the same rate of corrosion as it would have if the copper-base alloy were absent. A small area of a less noble metal in contact with a large area of a copper-base alloy may suffer from very rapid corrosion. For example, a brass fitting in an iron pipe line will do relatively little to accelerate the corrosion of the iron. On the other hand, an iron fitting in a brass or copper line will frequently suffer from rapid corrosion. The areas affected in this type of corrosion are usually limited to within several inches of the point of contact, if the corrosive water has a nigh electrical resistance.

Commonly Used Galvanic Couples. The coupling of various copper alloys with one another is not harmful. For example, bronze fittings and brass piping are commonly joined together without any noticeable acceleration of corrosion. On the other hand, the coupling of copper alloys with iron is common in equipment handling fresh water. For example, copper and brass tubes are used in conjunction with thick steel tube sheets in heat exchangers, where river water or lake water is used for cooling purposes, without excessive acceleration of corrosion of the steel tube sheets. This is possible because the surface area of the tube sheet and water box is large compared with the small effective area of the copper base alloy tubes. The acceleration of corrosion that occurs under these circumstances is not especially serious since the tube sheets usually are quite thick.

Effect of Grounding. The effect of grounding of electrical circuits on water pipe has been the subject of controversy for a long time. The most convenient procedure is to ground all electrical appliances to the nearest water line. This arrangement permits the electric current to flow through the water pipe of the building into the underground water system where it is dissipated into the ground or carried back to the power station. It has been suspected that current flowing through the water pipes may increase the internal corrosion of the water line.

At this point it is necessary to distinguish between internal and external corrosion of pipe lines. Much research on external corrosion of pipe lines has resulted in the development of good working

theories, and the remedies formulated have been used and proven over a period of many years.

Measurements have shown that electric currents may or may not be flowing on the surfaces of corroding brass pipes. Currents of the same order of magnitude may also be found flowing on brass pipes that are undergoing only very slight corrosion. This situation led only to confusion since it was impossible definitely to correlate the flow of current, either alternating or direct, with the extent of corrosion.

Recently Rolf Eliassen and Philip Goldsmith (4) conducted tests on grounded red brass, copper, galvanized iron, and lead pipes. Three lengths of each alloy were subjected to the following conditions: "One pipe of each type was subjected to a grounding current of 1.25 amperes of alternating current. The second pipe was subjected to 1.25 amperes of direct current. The third pipe was completely insulated so no superimposed current was applied." The results of these experiments indicated that no appreciable difference could be determined in the form of increased or decreased concentrations of metallic products of corrosion by the superimposed current. Any differences that might possibly have existed were far outweighed by the many other factors affecting the corrosion of metallic pipe. Concentrations of metallic products of corrosion in the water retained in the pipes were remarkably close, regardless of whether the pipes were subjected to alternating, direct, or no current. It appears from this evidence that a current flowing through a water pipe has only slight, if any, influence on the extent of corrosion occurring on the inside of the pipe.

Effect of Deposits. As discussed earlier in this paper, certain types of mineral deposits may be highly protective to the underlying metal. Here we shall consider the nature of the corrosion films that may form on metal. These corrosion films in the main may be considered as belonging to two classes: (1) thick visible non-protective films and (2) invisible protective films. It must be remembered that there are numerous films that have characteristics that lie between these two extremes.

The visible films that are insoluble in the corroding medium usually have the following characteristics:

1. They are permeable to water, *i.e.*, they permit the flow of water through them.

2. They are sufficiently dense to impede the flow of water to the metal surface. This may also slow up the rate of corrosion in some instances.

3. They are non-uniform or discontinuous, thus permitting the corrosive water more readily to come into contact with the metal in certain areas and partially to screen the metal in others.

4. The corrosion may be increased in certain screened areas by the formation of concentration cells that may result in the production of deep pits or plug-type dezincification.

5. The metal under the partially permeable film (anodic area) usually is attacked by localized corrosion (pitting).

6. The exposed metal, or the area covered with thinner films, usually is only slightly corroded (cathodic area).

7. The continued accumulation of corrosion products of the same type helps to produce deeper pits or to enlarge the area being corroded.

These properties of visible corrosion films aid in the formation of the concentration-cell type of corrosion. The corrosion cell begins to operate when the corroding substances are present in different concentrations at adjacent areas on the metal surface. The nature and distribution of sand and slime from various growths—weeds, leaves, silt, ashes, shells, pieces of rust, etc.—also are very important contributors to cell types of corrosion. In Figure 3 is shown some localized corrosion (plug-type dezincification) that occurred on the bottom of horizontal lines of yellow brass pipe by material settling out of the water.

In all instances the metal is corroded (anodic area which is pitted or dezincified) where the oxygen concentration is least. This usually occurs wherever the metal surface is shielded by a permeable deposit or in a crevice, such as a thread. Where no deposit covers the metal (cathodic area) and, therefore, the oxygen concentration is highest (the thin film is more permeable to oxygen), the corrosion rate is lowest since the cathodic reaction can here proceed with the greatest ease.

Effect of Crevices. The crevices produced by one means or an-

FIG. 3.—VIEW OF TOP AND BOTTOM SECTIONS OF A HORIZONTALLY-HELD SECTION OF YELLOW BRASS PIPE. NOTE NODULES OF CORROSION PRODUCTS COVERING AREAS OF PLUG-TYPE DEZINCIFICATION IN BOTTOM HALF.

other function in a manner very similar to certain types of deposits on metal surfaces. For example, pipe threads and threads on nuts and bolts and sharp corners are especially susceptible to localized corrosion, such as dezincification, pitting, or removal of the thread. See Figure 4.

In Figure 5 we have assumed that the rate of corrosion in the

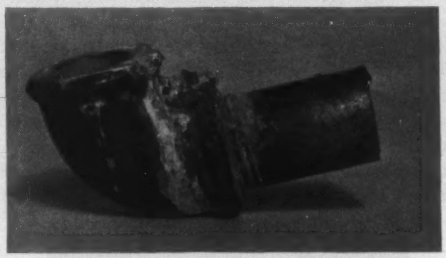

FIG. 4.—FAILURE OF BRASS PIPE AT THREADED CONNECTION DUE TO CREVICE CORROSION. PIPE BROKE OFF AT ELBOW.

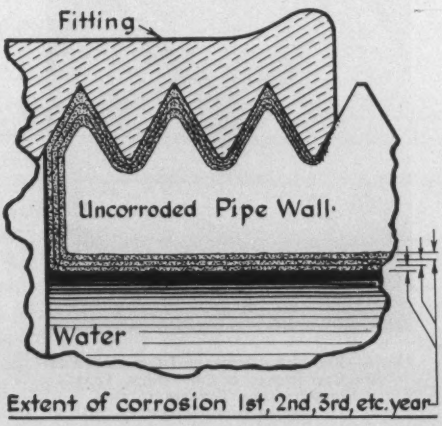

FIG. 5.—CORROSION IN THE THREAD AND ON THE INSIDE SURFACE OF PIPE.

thread is the same as that occurring on the interior of the pipe. It is evident that the probable life of a pipe handling a corrosive fresh water is approximately half that which would be obtained if no corrosion took place on the threaded portion. In addition, the cutting of a thread in a pipe frequently reduces the effective wall thickness. Sometimes this may be reduced by as much as one-half the original wall thickness. This means that the overall service life of a water pipe with a threaded joint may be reduced to at least one-quarter of that which should be expected based on the original overall wall thickness. In most instances in which early failures have occurred, the reduction in life has been even greater, because the crevice corrosion occurring in the threaded area was even more intense than that assumed in the illustration.

In Figure 6 is shown a photomicrograph of a dezincified section of pipe that had carried an aggressive soft non-scale-forming water.

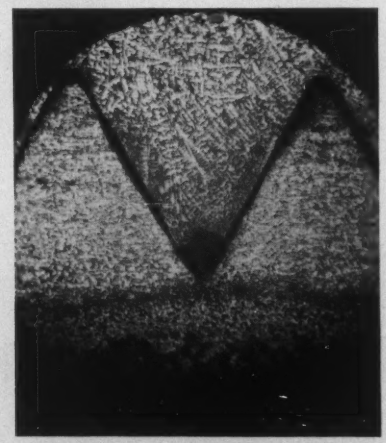

FIG. 6.—PHOTOMICROGRAPH OF DEZINCIFIED PIPE AND CAST-BRONZE ELBOW. NOTE THAT DEZINCIFICATION EXTENDS TO THE BASE OF THE THREADS.

The cast-bronze fitting is in excellent condition, and the threads on the yellow-brass pipe are in good condition since localized corrosion in the thread was overcome by filling the crevice between the pipe and the fitting with a suitable dope.

Since the thread (Figure 6) cuts the effective wall thickness approximately in half, a solder joint with a tube wall one-half the thickness of the brass pipe should be just as satisfactory. See Figure 7.

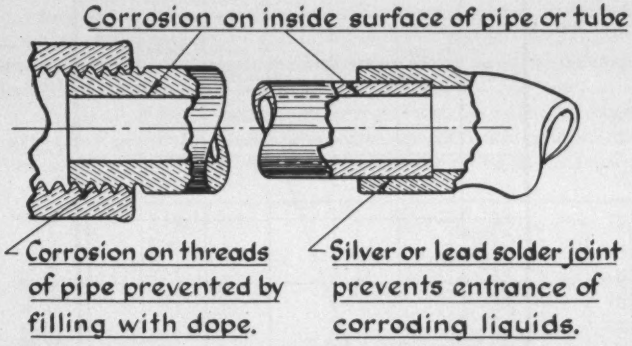
Corrosion on inside surface of pipe or tube
Corrosion on threads of pipe prevented by filling with dope.
Silver or lead solder joint prevents entrance of corroding liquids.

FIG. 7.—TWO METHODS OF PREVENTING CREVICE CORROSION.

Effect of Temperature. The effect of temperature upon corrosion varies considerably, depending upon circumstances. We shall consider four possible effects.

1. Where the metal is at the same temperature as the corrosive medium and rapid dezincification or pitting may result.

2. The "hot-wall-effect" where heat is transferred through a tube wall to the water being heated, as in hot water heaters.

3. Rapid oxidation of the metal at elevated temperatures especially where protective mineral or corrosion scales may form at an elevated temperature (more readily than at earth or room temperature) which allows the metal temperature to rise.

4. The "cold-wall-effect" which results in the sweating of pipes which occasionally leads to season cracking.

Metal and Water at Same Temperature. In Figure 8 is shown the change in corrosion rate with temperature. This curve indicates that qualitatively a temperature rise of the corroding solution of about 20° C. will double the rate of corrosion. Under service conditions, the effect of temperature may not be so pronounced; on the

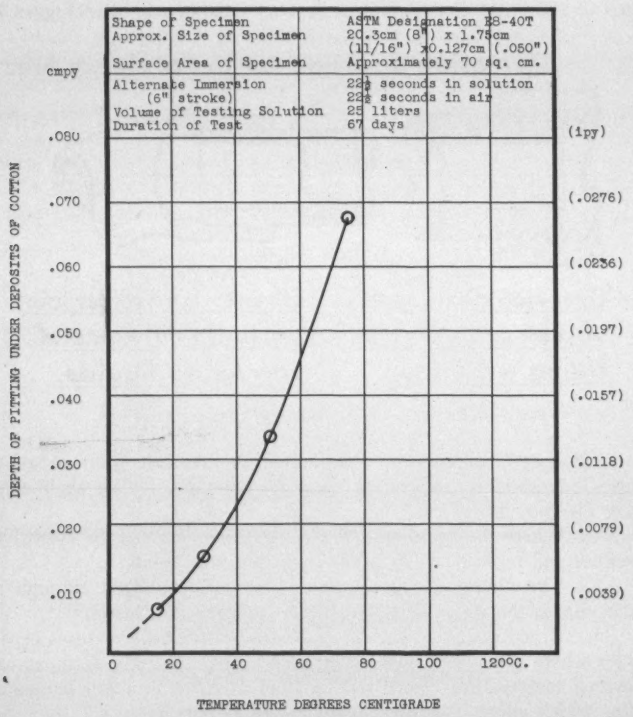

FIG. 8—EFFECT OF TEMPERATURE ON RATE OF CORROSION OF ADMIRALTY METAL IN 3% SODIUM CHLORIDE SOLUTION.

other hand in some cases the effect may be even more pronounced than this.

In Figure 9 the (a) variations in temperature, and (b) rate of corrosion in an estuary are plotted against the seasons of the year (5). It is evident that as the temperature rises and falls the corrosion rate also rises and falls. At the same time the bacterial activity also rises and falls so that it is difficult in this instance to determine which factor was the most important.

In warm and hot water, susceptibility toward pitting or dezincification generally increases substantially. In numerous investigations practically no corrosion occurred in the cold water lines, but rapid dezincification took place in the hot water lines.

Hot-Wall Effect. Sometimes severe local corrosion or pitting can rapidly perforate water-heater tubes on the water side at rates from 0.025 ipy up. The pitting occurs where bubbles of air separate

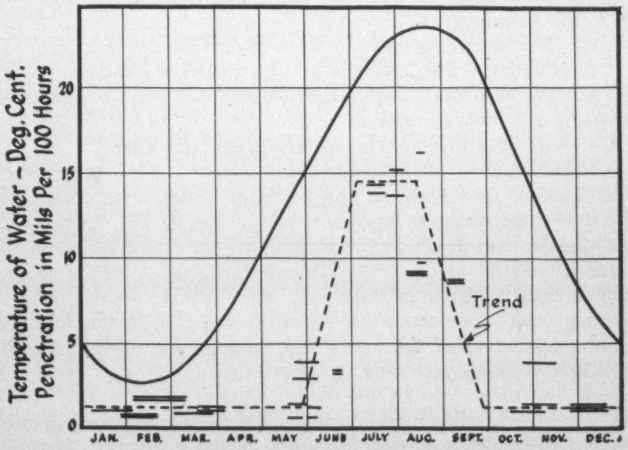

FIG. 9.—EFFECT OF TEMPERATURE ON RATE OF CORROSION.
Smooth curve records mean water temperature. Short horizontal lines represent results of individual tests, both magnitude and duration. Dotted line indicates approximate trend of results.

from the water. These bubbles of air hinder the water from cooling the metal surface and this allows local hot spots to form on the tube surface. This is called the "hot-wall-effect" (5).

The pits produced under these circumstances in copper alloys can be recognized easily since nodules of black or greenish-black corrosion products (essentially cupric oxide CuO) form over deep pits that are usually filled with bright red crystalline cuprus oxide (Cu_2O).

Apparently there are several important factors that accelerate corrosion at the point of bubble contact namely the combination of: (1) local high temperatures; (2) high concentration of corrosive agents separating out where the bubble forms; and (3) quantity of dissolved gas.

It is also probable that a fourth factor enters into this reaction, namely the composition of the gas bubble.

The mechanism of this corrosive action suggests the following preventive measures:

1. The temperature should be no higher than necessary.
2. Continued uninterrupted heating should be avoided.
3. The production of scratches on the metal surface might shift the point of bubble formation.
4. Air or gas should be removed from the water.

Oxidation at Elevated Temperatures. Unfortunately the build-up of a thick mineral scale on the inside of a heater tube or heat-exchanger tube seriously interferes with heat transfer. This loss in heat transfer may result in considerably higher temperatures on the metal surfaces facing the fire or hot vapors. This, in turn, may lead to more rapid oxidation of the metal. Such failures are described as resulting from "overheating" or actual "burning". In this instance, direct combination of the metal with atmospheric oxygen may be considered to occur according to the reaction:

$$2\,Cu + O_2 \rightarrow 2\,CuO$$

This corrosive reaction may take place without the intermediate steps involved when metals corrode in water. In this connection, however, we may also have occurring on the water side of the tube, or metal surface, localized corrosion that can be described in terms of the "hot-wall effect".

Cold-Wall Effect. The condensation of water vapor on the cold metal surface leads to the formation of drops of water, which under most conditions produce little or no corrosion. Occasionally, an unusual situation is encountered where the water droplet can absorb small amounts of corrosive materials, such as hydrochloric acid, ammonium hydroxide, sulfur dioxide, and ammonium sulfate. This may lead to the formation of deep corrosion grooves.

The contamination of a condensate by ammonia or nitrogen compounds, from steam or products of combustion (from coal or gas-fired furnaces and water heaters) may lead to stress-corrosion-cracking of stressed brass condenser tubes or basement cold-water pipe. This stress corrosion is very highly localized and is characterized by many narrow cracks that penetrate the metal from the surface facing the corrosive atmosphere or solution. Sometimes it consists of a single crack which eventually splits the tube longitudinally.

The time required to penetrate a brass tube or pipe varies considerably (from a few hours or days to many years), depending upon: (1) the amount of ammonia or similar nitrogen compound; (2) the magnitude of the stresses; (3) the inherent susceptibility of the alloy to this specific type of attack; (4) the amount of water vapor; and (5) the amount of air.

Stress-corrosion cracks appear in copper alloys only when all five of these factors obtain simultaneously. Consideration of the mechanism of stress corrosion suggests several ways of preventing cracking due to the cold-wall effect:

1. Maintenance of a dry surface is advisable wherever possible. For example, stress corrosion rarely occurs in hot-water lines, because they are generally free from condensates. Insulating cold-water pipes also helps to combat outside-surface corrosion.
2. Keeping the stresses down to a minimum.
3. Selection of a more stress-corrosion-resistant copper-base alloy is advisable when these precautions (1 and 2) are not feasible. For example, red-brass, copper, 70-30 cupro-nickel, aluminum bronze, etc.

Effect of Velocity of Water. In some instances, only a slight movement of a corrosive liquid is required to start rapid localized corrosion of certain copper-base alloys. This condition usually pre-

vails at those points where the water is flowing in bent pipes or tubes, through wire screens, and where the cross-sectional area of a pipe system is suddenly reduced. A common example of the latter is found in heat exchanger and condenser tubes where the movement, or turbulence, of water at the inlet end of tubes frequently leads to localized corrosion (generally thinning and pitting), commonly called "inlet-end corrosion". This is much more intense in sea water than in fresh water.

When another phase is present in the water stream such as sand and other debris and gas bubbles, the effect of velocity becomes even more serious. For example, when much entrained air is present in the water stream, pits undercut at the forward end may form at those points where the gas bubbles impinge on the metal surface. This type of corrosion is usually called "impingement corrosion". Arsenical aluminum brass, 70-30 cupro-nickel containing iron, certain aluminum bronzes, and high-tin bronzes show good resistance to this type of attack. This accounts for the widespread use of these alloys in sea water and other saline solutions. While copper and the brasses resist the action of impinging streams of fresh water very well, it is occasionally necessary to change from copper and the copper-zinc alloys in certain fresh water installations to the before mentioned alloys, since copper and the unmodified copper-zinc alloys may not stand up very well under these conditions.

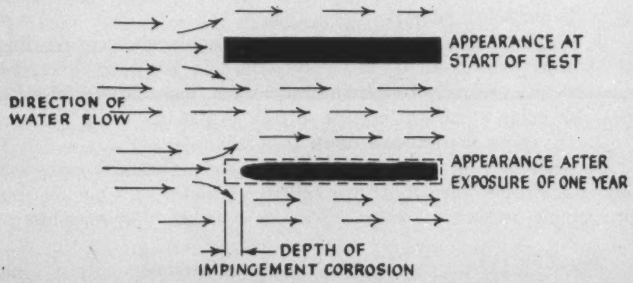

FIG. 10.—CHANGE IN APPEARANCE OF THE LEADING EDGE OF SPECIMENS DUE TO IMPINGING STRAIN OF SEA WATER.

The effect of velocity may be recognized in two ways. The leading edges of protruding metal surfaces may be rapidly reduced in size as shown in Figure 10. This condition is especially noticeable on the upstream side of the leading edge or at the corners where the cross-sectional area of piping systems is suddenly reduced. Impingement-corrosion pits are recognized by undercutting of the pits on the downstream side. The pits that form are quite clean and free from corrosion products of any type. Sometimes these pits have a noticeable tail pointing upstream as shown in Figure 11. Frequently a series of pits will overlap giving a serrated profile when a longitudinal section of tubing or pipe is examined.

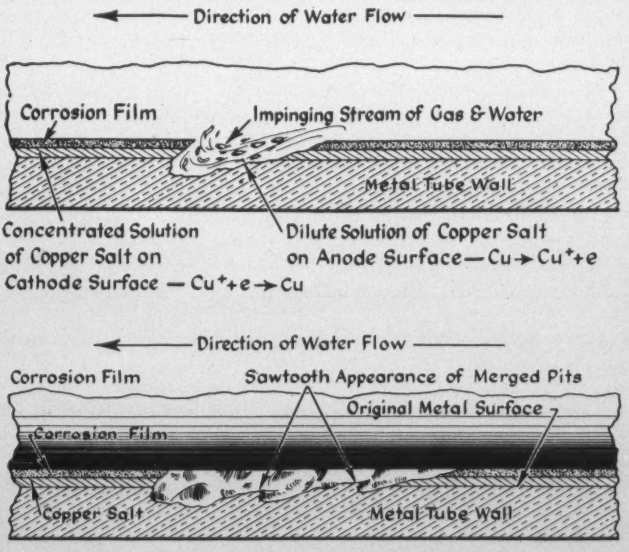
Direction of Water Flow
Corrosion Film
Impinging Stream of Gas & Water
Metal Tube Wall
Concentrated Solution of Copper Salt on Cathode Surface — $Cu^{+}+e \rightarrow Cu$
Dilute Solution of Copper Salt on Anode Surface — $Cu \rightarrow Cu^{+}+e$
Direction of Water Flow
Corrosion Film
Sawtooth Appearance of Merged Pits
Original Metal Surface
Corrosion Film
Copper Salt
Metal Tube Wall

FIG. 11.—PITS FORMED BY IMPINGEMENT CORROSION.

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SANITATION MANUAL FOR PUBLIC GROUND WATER SUPPLIES*

Prepared by the United States Public Health Service

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Introduction

This manual has been prepared by the Public Health Service for the guidance of States, municipalities, and health districts in order to encourage a greater uniformity and a higher level of safety in the sanitary control of public ground water supplies.

The Public Health Service, in 1937, appointed a Water Sanitation Advisory Board to consider the formulation of a water supply section as a part of a general sanitation code. This Board at a number of meetings prepared some of the material necessary for a water supply section. In 1940, the Public Health Service undertook to prepare a code on ground water supplies utilizing much of the material formulated by the Sanitation Advisory Board. Several drafts of such a code were referred to the State health officers for review and comment.

Serious objections were voiced to the use of the ordinance and code form and the sentiment in general appeared to be that a manual or guide of recommended practice was preferable. This manual has been prepared with the thought of indicating desirable practice or, more correctly, minimum acceptable standards. The form followed in other Public Health Service manuals has been adopted in this manual, that is: statement of the requirement, the public health reason for the requirement, and what constitutes satisfactory compliance.

The word "shall" has been used throughout the manual to state what must be done to accomplish satisfactory compliance. Because this is a manual or guide, objection may be voiced to this terminology. However, the word "shall" has been used advisedly to permit adoption of the material without extensive editing and revision, if so desired. Where the manual is used as a guide in the preparation of other regulations or is revised to suit the needs of a particular health authority no harm will result from the use of the word "shall" throughout in this manual.

This manual will be subject to periodic review and revision for incorporation of such changes as will increase its usefulness.

SANITATION MANUAL FOR PUBLIC GROUND WATER SUPPLIES

Section 1. Definitions

1. Public water supply. A public water supply is one from which water may be distributed, sold, or made available to the people at large or to any considerable number of members of the public indiscriminately.

2. Public ground water supply. A public ground water supply is a public water supply which obtains water from subsurface sources.

3. Bottled water. Bottled water means any water distributed, sold, or made available to consumers in bottles or other containers.

4. Health officer. Health officer means the health officer of any State, municipality, or district which adopts these requirements, or his duly authorized representative.

5. Person. Person means an individual, a partnership, a public or private corporation, an association, a joint stock company, a trust, or an estate.

6. Cross-connection. Any physical connection whereby the approved supply is connected with any other water supply system whether public or private, either inside or outside of any building or buildings in such manner that a flow of water into the approved water supply is possible either through the manipulation of valves or because of ineffective check or back pressure valves, or because of any other arrangement.

7. Backflow connection. Any system of piping or other arrangement whereby the public water supply is connected directly with a sewer drain, conduit, pool, storage reservoir, or other device which does or may contain sewage or other waste or liquid which would be capable of imparting contamination to the approved water supply.

8. Auxiliary intake. Any piping connection or other device whereby water may be secured from a source other than that normally used.

9. Bypass. Any system of piping or other arrangement whereby the water may be diverted around any part or portion of a water purification plant.

Section 2. Registration and Permits

From and after the date of adoption and publication of requirements for public ground water supplies by a State, municipality, or district, no person shall begin construction, alteration, or extension of any public ground water supply without first securing a written permit from the State health officer. Such permit shall be granted by the State health officer only after examination and approval of detailed plans and specifications which shall have been submitted by said person, or after such survey of the site or installation as the State health officer may deem necessary.

Not later than 6 months after the adoption and publication of requirements for public ground water supplies by a State, municipality, or district, all persons who own or control any public ground water supply shall submit to the health officer a report giving such information relative to said water supply as may be required by the health officer.

Section 3. Inspections

At least once during each 12-month period the health officer shall inspect all public ground water supplies in his jurisdiction for the purpose of ascertaining which supplies shall be termed "Approved Public Ground Water Supplies."

In case the health officer discovers any violation of the requirements which have been adopted, he shall require correction of such violations in writing specifying the corrections to be made and the time allowed for making them. A second inspection shall be made after the lapse of the time allowed for the defects to be remedied and the second inspection shall determine whether or not the supply shall be "approved."

Section 4. Emergency Measures To Prevent Epidemics

Whenever, in the opinion of the health officer, conditions arise in connection with any public ground water supply which warrant emergency measures to prevent a water-borne disease epidemic, said health officer is authorized to apply such measures as he may deem necessary.

Section 5. Approved Public Ground Water Supplies

All "Approved Public Ground Water Supplies" shall conform with the following items of sanitation:

ITEM 1. EXCLUSION OF SURFACE WATER FROM SITE

The site of the source in all directions shall not be subject to flooding and shall be so graded and drained as to facilitate the rapid removal of surface water.

Public health reason.—The exclusion of flood waters from the site and proper drainage of surface water away from the source will help to prevent contaminated surface water from reaching the source directly. If flood waters are excluded for a given horizontal distance, such waters may reach the source only by passage through the soil in the intervening distance, thereby providing a factor of safety against direct pollution.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Pump platform, pump room floor, or cover of a ground water supply is not less than 2 feet above the highest known high water level of any nearby body of surface water. Where necessary the area should be filled and graded to the necessary height and filling protected from erosion by rip rap.

(2) Flood waters from nearby bodies of surface water are not allowed to approach within less than 50 feet of the source measured horizontally.

(3) The earth surfaces are sloped to drain away from or divert surface water around the spring, infiltration system, well, or pump house, and are so graded and maintained as to prevent the accumulation and retention of surface water within a distance of 50 feet from the source in all directions.

(4) For hillside sites, an adequate intercepting ditch or ditches are constructed around the uphill side of the source in such manner and so maintained as to keep hillside storm water at least 50 feet away from the source in all horizontal directions; the intercepting ditch or ditches may be protected against erosion by rip rap, concrete, or other equivalent ditch lining where necessary.

(5) The source is not located in a ravine where surface water flows may be obstructed or concentrated.

ITEM 2. SATISFACTORY EARTH FORMATIONS ABOVE THE WATER-BEARING STRATUM

The earth formations above the water-bearing stratum shall be of such character and depth as to exclude contamination from the source. If satisfactory sites are not available the water shall be treated by a method or methods approved by the health officer for the specific installation.

Public health reason.—The earth formations above the water-bearing stratum should be of such depth and character as to provide filtration sufficiently adequate to prevent contaminated surface water from reaching the source. Formations such as limestone, broken lava rock, coarse gravel, and brittle rocks whose interstices are in the form of channels, joints, and fissures provide little filtering action to prevent contamination from reaching the water-bearing stratum.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) The earth formations overlying the water-bearing stratum (natural or fill) consist of one or more impervious formations such as clay, silt, stiff clay mixtures, fine sand, or equivalent materials having a combined depth of not less than 10 feet.

(2) The backfill above an infiltration system consists of not less than 10 feet of thoroughly compacted clay, silt, stiff clay mixtures, or equivalent materials.

(3) Treatment approved by the health officer is provided where satisfactory earth formations above the water-bearing stratum cannot be shown to exist. (Treatment may, of course, be required due to other unsatisfactory conditions even though satisfactory earth formations are known to exist).

ITEM 3. DISTANCES TO SOURCES OF CONTAMINATION

Every public ground water supply and all appurtenances thereto shall be located at a safe distance from all sources of contamination such as pit privies, cesspools, septic tanks, subsurface tile systems, sewers, drains, barnyards, and pits below the ground surface.

Public health reason.—The organisms of typhoid fever, dysentery, and other enteric diseases are present in the body wastes of persons

sick with these diseases or who are carriers of the diseases. If sources of contamination are located near the water supply source, disease organisms may reach the latter.

Ground waters located in formations such as limestone, broken lava rock, coarse gravel, brittle rocks, or equivalent materials which are not protected against the penetration of contamination by an adequate overlying impervious formation are not suitable for public ground water supplies without treatment.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) The distance from the water supply source to any means of contamination in all horizontal directions is not less than 50 feet. This minimum distance shall be used only where existing conditions indicate it to be sufficient; greater distances should be provided where local conditions indicate the need for greater protection.

(2) In case the area adjacent to the source is accessible to livestock, the site is completely surrounded by a fence located not less than 50 feet from the source in all horizontal directions. Drainage from areas accessible to livestock in the vicinity of water sources is away from the water source.

* * *

MINIMUM DISTANCES TO SOURCES OF CONTAMINATION

Because of the many factors involved in the determination of a "safe distance" from sources of contamination, the following information is given for the guidance of those concerned:

Every ground water supply source such as a well, spring, or infiltration system, and all appurtenances thereto, should be located at a safe distance from any cesspool, privy, septic tank, and tile field, sewer, soil pipe or pipe through which sewage may back up, or from any other possible source of pollution, and in such manner as to prevent contamination of the water by either underground seepage or channels, or by surface drainage. Coarse gravel, limestone, disintegrated rock, or other porous material which will permit rapid flow of water through it are not suitable materials around a source of supply. When such formations are encountered, more suitable sites should be obtained. If satisfactory sites are not available, adequate treatment of the water should be provided.

The location of ground water supplies on a side hill or at the foot of a hill where cesspools, privies, sewers, or other sources of pollution are situated on the slope above and in the path of the ground water flow and within 300 feet should be avoided.

When a body of ground water tapped by a well is drawn upon, the level

of the water in the well will be lowered, and the surface of the ground water adjacent to the well will assume a form similar to an inverted cone. The amount which the water level is lowered decreases rapidly at increasing distances from the well, until at some point, more or less remote, there is no perceptible effect. The area within which the level is lowered appreciably is called the circle of influence.

Where the rate of pumpage from a well exceeds the percolation of water through the water-bearing formation, the water level in the well will drop and the circle of influence will be broadened. For a specific well the drawdown or drop in water level and the diameter of the circle of influence will be much greater usually when pumped at high rates than when pumped at low rates. Because of this fact, ordinary wells which are developed and equipped to provide large volumes of water are more likely to become contaminated from sources of pollution located at greater distances as compared to wells supplying small volumes of water. It is essential, therefore, that the minimum distances between the well and sources of contamination be increased as the rate of pumpage from the well is increased.

* * *

The Minnesota Department of Health has developed a formula for computing approximate safe distances between wells and sources of contamination based on the character of the soil, the capacity of the pump, the permissible velocity through the soil, the slope of the surface or water table, and the length of the screen or depth of flow toward the well. This formula, and tables computed by its application, are presented here:

Let D=Distance between well and the source of contamination, in feet.

P=Pump rate, in gallons per minute.

L=Length of well screen, depth of flow toward well, or thickness of water-bearing formation, in feet.

S=Angle of slope of ground in degrees (approximately parallel to the water table).

K=Coefficient of flow depending on character of soil.

For fine sand:

K=0.11 gallons per square foot per minute.

For medium sand:

K=0.07 gallons per square foot per minute.

For coarse sand and gravel:

K=0.03 gallons per square foot per minute.

When the distance D is such that the limiting velocity K is not exceeded, then the total flow = pump effect plus slope effect.

$$2\pi DLK = P + 2\pi DL (K \text{ sine } S)$$

Solving for D.

$$D = \frac{P}{2\pi LK (1 - \text{sine } S)}$$

This formula is not accurate beyond the limits of accuracy of the data used

in it. It should not be taken to give definite safe distances, but it has been found useful in checking judgment of distances in the preliminary study of well sites. Careful consideration must always be given to the geological formations on the site especially where there may be faults, ledges, or impermeable dams that interfere with the expected movement of the water.

This formula can be used to develop tables for checking existing installations or decisions regarding new sites. For those who have an aversion to working out a mathematical formula, the table would be helpful. Skeleton tables can be set up and the formula used to fill in any intermediate conditions. To illustrate the working of the formula and table, the following is presented:

Let P=500 gallons per minute.

L=15.

K=0.11.

S=0.

$$D=\frac{500}{2\times 3.14\times 15\times .11}=50.$$

For S=8° D=58 feet, say 60 feet.

For S=16° D=68feet, say 70 feet.

The formula can be used to determine the approximate safe distance for any combination of screen, pump, soil, and slope with the proviso that no distance shall be less than the 50, 40, and 30 feet that head the 500-gallons-per-minute table. Hand pumps and power pumps of small draft will fall, therefore, under the classification.

TABLE 1.—*Pump capacity 500 g.p.m.—15-foot screen*

Character of soil	Degree of slope	Type of structure containing pollution: Cesspools, privies, and clap pipe sewers	Cast iron pipe, and metal tanks	Sewer connections with extra-cased special joints
		A	B	C
Silt and clay Very fine sand (0.1 mm. and less)	0	50	40	30
	8	60	50	40
	16	70	60	50
Fine sand to Medium sand (0.1 mm. to 0.5 mm.)	0	75	65	55
	8	90	80	70
	16	105	95	85
Coarse sand Fine gravel and well filled mixed gravel (0.5 mm. to 2.0 mm.)	0	175	165	155
	8	200	190	180
	16	240	230	220

The two paragraphs following are quoted from "Ground-Water Supplies. Progress Report of the Committee on Ground-Water Supplies Conference of State Sanitary Engineers, 1936" (Supplement No. 124 to the Public Health Reports).

"Toilets, sewers, floor drains, soil pipes, main drains, or other pipes which are connected directly to a storm or sanitary sewer, or through which water or sewage from any source may back up, should not be located nearer than 50 feet, horizontally, to any well, spring, infiltration system, pumping apparatus, suction

TABLE 2.—*Pump capacity 1,000 g.p.m.—15-foot screen*

Character of soil	Degree of slope	Type of structure containing pollution: Cesspools, privies, and clap pipe sewers	Cast iron pipe, and metal tanks	Sewer connections with extra-cased special joints
		A	B	C
Silt and clay	0	100	90	80
Very fine sand	8	120	110	100
(0.1 mm. and less)	16	140	130	120
Fine sand to	0	150	140	130
Medium sand	8	180	170	160
(0.1 mm. to 0.5 mm.)	16	210	200	190
Coarse sand	0	350	340	330
Fine gravel and well filled mixed gravel	8	400	390	380
(0.5 mm. to 2.0 mm.)	16	480	470	460

A—Computed by formula.
B—Arbitrary deduction of 10 feet from A for reducing the possibility of contamination.
C—Deduction of 10 feet from B when amount of contamination escaping into the soil is further limited. Column C represents the minimum distance for any type of construction.

main, air pipe, air compressor, filter, or other feature of any ground-water supply. In special cases, where it is impossible or not practical to obtain a 50-foot distance, special construction to provide additional safeguards is necessary. In no case shall such fixtures or piping be nearer than 30 feet to a well. All such sewers, drains, and pipes, or parts thereof, which must be more than 30 feet and which are less than 40 feet, horizontally, from any such water supply feature, should be constructed of extra heavy cast iron pipe with tested watertight leaded joints. In this zone, joints should be further protected against leakage by a substantial slip-over sleeve extending at least 6 inches from each side of the joint. The annular space between the pipe and the sleeve shall be filled with asphalt or material such as sewer-joint compound, or closed with rubber gaskets. All such sewers as lie between 40 and 50 feet of the ground-water supply may be of extra heavy cast iron pipe with tested watertight leaded joints. Toilets, sewers, soil pipes, or drains should not be located on the first floor directly above the pump-room floor, or where leakage therefrom can reach any source of water supply or pump room.

"Floor drains constructed of cast iron pipe with leaded joints may be located as close as 2 feet to a ground-water supply, provided they do not connect to a storm or sanitary sewer, and provided they discharge only to the ground surface or to a gravel pocket, which is well removed from contact with sewage or other waste. The cast iron pipe should be carried to a point at least 4 feet outside the building walls and connected to other suitable pipe which discharges at least 30 feet from the ground-water supply."

ITEM 4. MINIMUM DEPTH OF CASINGS AND CURBINGS

All well and spring basin casings or curbings shall extend a safe distance below the ground surface.

Public health reason.—A watertight casing or curbing which extends a safe distance below the ground surface is essential to insure exclusion of contaminated water from a well.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) The watertight well casing or curbing extends to a minimum depth of not less than 10 feet below the ground surface and preferably 10 feet below the ground water table. The casing should be carried through an impervious stratum above the water-bearing stratum and a tight seal made between this impervious stratum and the well casing to exclude undesirable water strata and surface water. Where such impervious strata may not exist, the well should be grouted throughout its entire depth to seal off all but the water-bearing stratum from which water is to be drawn.

(2) The watertight casing for a driven point well extends the full depth of the well to the water-bearing stratum.

(3) In the case of springs, the water enters the inclosing structure of springs or infiltration systems at points 10 feet below the ground surface. In cases where the 10-foot distance is not obtainable without sealing, cutting off, or diverting the underground source, the springs may be protected by placing earth filling over the area involved (50-foot radius from the spring) to provide the necessary depth of 10 feet of earth over the points of flow. If this is impracticable, adequate treatment should be provided in accordance with the provisions of Item 20 of this manual.

ITEM 5. CONSTRUCTION AND USE OF CASINGS AND CURBINGS

All ground water supplies shall have a properly constructed and installed outside watertight casing or curbing extending a safe distance above and below the ground surface.

Public health reason.—A properly constructed and installed watertight casing or curbing is essential to prevent the entrance of surface or subsurface contamination into the well.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) If metallic casings are used the casing is new standard steel, wrought iron, or cast iron as specified in the following tables or equal,

and the pipe sections are threaded or welded so as to be watertight.

(*a*) In establishing the depth of casing or curbing below the ground surface, the measurement is made from the established grade in the immediate vicinity of the source. The casing or curbing shall extend as far as practicable below the natural ground level, but not less than 10 feet, and excessive depths of fill should be avoided.

(*b*) the annular space between the outside well casing and the well hole, for drilled wells, is filled with not less than 1½ inches of impervious cement grout to a depth of at least 10 feet and to such greater depth as may be required by the health officer. Refer to Appendix A for discussion of cement grouting of drilled wells.

(*c*) Telescoping casings of different diameters, in a drilled well, overlap at least 8 feet and the annular space between such casings is filled with not less than 1½ inches of impervious cement grout or with a lead packer to prevent admission of undesirable ground water or surface drainage.

(*d*) The outside casing is not used as a suction or working barrel for pump plungers.

(2) The casing extends not less than 6 inches above the established ground surface at the well or the floor of the pump house.

(3) If concrete pipe, vitrified tile pipe, cement asbestos pipe, galvanized well casing, corrugated metal pipe, or brick are used for curbings for wells or springs, the following requirements are satisfied:

(*a*) Vitrified tile pipe, cement asbestos pipe, galvanized well casing, corrugated metal pipe, and concrete pipe shall be surrounded by not less than 6 inches of concrete to a depth of at least 10 feet. The surrounding concrete wall shall be not less than 6 inches thick, properly reinforced, and the concrete shall be so placed as to be free from voids. Wherever practical, the wall shall be poured in one operation, but in no case shall there be a construction joint within 10 feet of the top of the curbing. Where construction joints are essential at points more than 10 feet below the ground surface they shall be left rough and shall be washed and brushed with neat cement grout prior to pouring concrete.

The concrete used in the construction of any ground water supply units should be composed of 1 part Portland cement, 2 parts sand, and 4 parts gravel by volume. Clean, hard, tough, and durable aggre-

TABLE 3.—*Steel and wrought iron well casing*

Nominal size in inches	Well casing: Weight, pounds per foot (Threads and couplings, inclusive)	Well casing: Thickness in inches	Diameter in inches: Internal	Diameter in inches: External	Couplings: Threads per inch	Couplings: Length in inches	Couplings: External diameter in inches
1	1.68	0.133	1.049	1.315	11½	1⅞	1.576
1¼	2.28	.140	1.380	1.650	11½	2⅛	1.950
1½	2.73	.145	1.610	1.900	11½	2⅜	2.218
2	3.68	.154	2.067	2.375	11½	2⅝	2.760
2½	5.82	.203	2.469	2.875	8	2⅞	3.276
3	7.62	.216	3.068	3.500	8	3⅛	3.948
3½	9.20	.226	3.548	4.000	8	3⅜	4.591
4	10.89	.237	4.026	4.500	8	3⅝	5.091
4½	12.64	.247	4.506	5.000	8	4⅛	5.591
5	14.81	.258	5.047	5.563	8	4⅛	6.296
6	19.18	.280	6.065	6.625	8	4⅛	7.358
8	25.00	.277	8.071	8.625	8	4⅝	9.420
10	35.00	.307	10.136	10.750	8	6⅛	11.721
12	45.00	.330	12.090	12.750	8	6⅛	13.958
14 OD	57.00	.375	13.250	14.000	8	7⅛	15.446
15 OD	61.15	.375	14.250	15.000	8	7⅛	16.446
16 OD	65.30	.375	15.250	16.000	8	7⅛	17.446
17 OD	73.20	.375	16.214	17 000	8	7⅛	18.683
18 OD	81.20	.375	17.182	18.000	8	7⅛	19.921
20 OD	90.00	.375	19.182	20.000	8	7⅝	21.706

Where pipe sections are connected by welded joints, threading and couplings are not essential.

TABLE 4.—*Threaded cast iron well casing*

Nominal diameter (inches)	Well casing: Weight, pounds per foot	Well casing: Wall, thickness in inches	Diameter in inches: Internal	Diameter in inches: External	Maximum length of string in feet	Couplings: Threads per inch	Couplings: Length in inches	Couplings: External diameter in inches
3	11.2	0.360	2.780	3.500	1,200	8	3½	4.125
3	12.2	.360	3.155	3.875	1,200	8	3¾	4.750
3	12.7	.360	3.240	3.960	1,200	8	3¾	4.875
4	15.0	.370	3.760	4.500	1,200	8	4	5.250
4	17.0	.380	4.040	4.800	1,200	8	4	5.750
4	17.2	.380	4.240	5.000	1,200	8	4	6.000
5	18.5	.380	4.803	5.563	1,200	8	4¼	6.375
6	24.4	.400	5.825	6.625	1,200	8	4½	7.500
6	27.0	.430	6.040	6.900	1,200	8	4½	7.875
6	28.1	.430	6.240	7.100	1,200	8	4½	8.250
8	36.7	.460	7.705	8.625	1,400	8	5	9.625
8	42.0	.500	8.050	9.050	1,400	8	5	10.125
8	43.1	.500	8.300	9.300	1,400	8	5	10.625
10	52.1	.520	9.710	10.750	1,400	8	5¼	12.000
10	59.0	.570	9.960	11.100	1,500	8	5¼	12.500
10	60.5	.570	10.260	11.400	1,500	8	5¼	13.000
12	69.2	.580	11.590	12.750	1,500	8	5¾	14.125
12	77.0	.620	11.960	13.200	1,500	8	5¾	14.625
12	78.3	.620	12.260	13.500	1,500	8	5¾	15.250
14	99.0	.690	13.920	15.300	1,500	8	6¼	16.875
14	102.0	.690	14.270	15.650	1,500	8	6¼	17.625
16	122.0	.750	15.900	17.400	1,600	8	6¼	19.250
16	126.0	.750	16.300	17.800	1,600	8	6¼	20.000
18	152.0	.830	17.840	19.500	1,600	8	7	21.250
18	156.0	.830	18.260	19.920	1,600	8	7	22.375
20	179.0	.880	19.840	21.600	1,600	8	7½	23.625
20	183.0	.880	20.300	22.060	1,600	8	7½	24.625
24	243.0	1.000	23.800	25.800	1,600	8	8¼	28.125
24	248.0	1.000	24.320	26.320	1,600	8	8¼	29.250

Where pipe sections are connected by welded joints, threading and couplings are not essential.

gates should be used. The maximum diameter of aggregate particles should not exceed one-fifth of the minimum width between forms. Hydrated lime to the extent of 10 per cent of the volume of cement may be added to increase fluidity and facilitate placement of concrete. The use of lime is particularly applicable in the case of concrete used for spring and dug well casings.

(*b*) Single brick walls. Single brick walls shall be surrounded by not less than 6 inches of concrete as described in paragraph (*a*).

(*c*) Double layer brick walls have an inch thick layer of 1 to 1 Portland cement mortar applied either to the exterior of the brick wall or between the two rings of brick. Both the vertical and horizontal joints in the two rings of brick are staggered. The brick is common brick, compact in texture, hard burned entirely through, sound and uniform in quality and free from lumps and cracks.

(*d*) Well and spring basin curbings extend at least 6 inches above the established ground surface.

(*e*) The peripheral space between a dug well or a spring basin curbing and the original earth formation is filled with thoroughly compacted clean puddled clay or equivalent materials.

(*f*) A separate inside pipe for conducting water from a well, commonly known as a drop pipe, is provided.

ITEM 6. GRAVEL TREATED WELLS

When gravel is placed in the annular space between the excavation line and the outside of the well casing, the gravel surface shall terminate a safe distance below the ground surface and the annular space above the gravel surface shall be filled with impervious material. It is desirable to disinfect the gravel used with a chlorine solution because it is practically impossible to do so after the gravel has been placed.

Public health reason.—Proper filling of the annular space between the excavation line and the outside of the well casing with impervious material for a safe distance above the gravel surface is essential to prevent contaminated surface water from reaching the source of supply through the gravel layer. The use of contaminated gravel may result in unsatisfactory bacteriological tests over a long

period of time and even if this gravel contamination has no sanitary significance it may mask the true quality of the ground water source.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) The gravel surface terminates not less than 10 feet below the ground surface.

(2) The annular space between the excavation line and the outside of the well casing, above the gravel surface, is filled with thoroughly compacted puddled clay, mortar, or cement grout.

(3) Gravel used for treating wells is disinfected with a chlorine solution immediately before application to the well.

ITEM 7. COVERS, PLATFORMS, AND FLOORS

Every cover, pump platform, or pump room floor shall be watertight and elevated above the adjacent ground level and its surface sloped to facilitate the rapid removal of waste water.

Public health reason.—A properly elevated, watertight, well-drained cover or floor promotes cleanliness and is essential to divert contaminated surface water away from the source.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) The cover, pump platform, or pump room floor is made of reinforced watertight concrete.

(2) The concrete is sloped from the center of the well casing or pipe sleeve to the outer edges of the slab or the drain, and the slab at its outer edges is not less than 4 inches thick.

(3) In the case of drilled or bored wells equipped with hand-operated pumps, the concrete slab extends not less than 2 feet from the well casing in all directions.

(4) In case power pumps are mounted over the casing, the casing extends not less than 6 inches above the pump platform or floor and not less than 1 inch into the pump base in accordance with the provisions of item 11 (B) of this manual.

(5) In the case of hand pumps, the casing or pipe sleeve extends not less than 1 inch above the pedestal on which the pump base rests.

(6) The cover of a dug well or spring basin is watertight, properly

grouted in place, and its edges extend at least 2 inches beyond the outer edge of the wall or curbing of the well or spring basin.

(7) In the case of drilled or bored wells, the cover, pump platform, or pump room floor rests on thoroughly compacted earth.

ITEM 8. WELL SEALS OR COVERS.

Every well shall be provided with a watertight seal or overlapping cover at the top of the casing or pipe sleeve.

Public health reason.—A watertight seal or overlapping cover at the top of the casing or pipe sleeve is essential to prevent contaminated water or other deleterious material from entering the well through the annular opening at the top of the well casing or pipe sleeve.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) In case the pump and drop pipe are not installed immediately after the casing or pipe sleeve is installed, the top of the casing or pipe sleeve is provided with a watertight seal or overlapping cover at the top until the installation is completed and a permanent seal is provided.

All wells should be kept permanently sealed, or properly covered, at the top at all times, except when necessary to remove the seal for the purpose of inspection or to accomplish necessary installations, repairs, or other essential operations.

(2) The casing or annular opening between the casing and drop pipe is provided with a watertight seal or overlapping cover, making a watertight connection to drop pipe, at the top. This item shall be satisfied when a properly constructed pump base overlaps the casing or pipe sleeve at the top.

ITEM 9. WELL VENTS

Well vents shall be constructed and installed to retain atmospheric pressure conditions in the well casing and to prevent the entrance of contamination.

Public health reason.—Proper construction and installation of a well vent is essential to prevent the entrance of insects and contaminating material into the well. Creation of a partial vacuum within

the well might tend to introduce pollution or cause collapse of the well wall or casing.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Every well in which the draw-down is 10 feet or more, and which has equipment or appurtenances installed therein, is provided with an adequate air vent.

(2) The air vent is constructed of metal tubing or pipe and connected so as to be watertight.

(3) The open end of the vent is screened and terminated in a downward direction through use of an elbow or equivalent means and the lower end of the outlet is not less than 12 inches above the top of the well casing, and in no case less than 18 inches above the floor of the pump room.

The vent shall be screened with 16-mesh brass or bronze screen, or holes ¼ to ½ inch in diameter may be drilled in the capped, downward directed portion of the vent pipe and 16-inch brass or bronze screen tightly fitted over these holes. The cross-sectional area of these holes should be at least equal to the cross-sectional area of the vent pipe.

ITEM 10. WELL PITS

Wellheads, well casings, pumps, pumping machinery, exposed suction pipes, or valve boxes connected with a suction pipe shall not be located in any pit, room, or space extending below the ground surface: *Provided,* That existing pits may be provisionally accepted only if constructed in accordance with the requirements of the State health department.

Public health reason.—Excavations or subsurface structures such as well pits provide means for the accumulation of contaminated surface or shallow subsurface water which may contaminate the water supply.

A number of sanitary pitless underground pumps are available on the market which eliminate the installation of underground discharge pumps in pits for frost protection. Standard parts can be purchased and assembled in such a way as to accomplish the same results. The need for frost pits may be avoided by the use of bleeders or weep holes

located in the drop pipe at a point below the frost line in order that the water in the pump and drop pipe may run back into the well after pumping has been discontinued. The need of locating pump room floors below the ground level may be avoided by providing an insulated pump house to protect the pumping equipment and appurtenances from freezing. If additional protection is essential during unusually cold weather, it can be provided at a nominal cost by installing a thermostatically-controlled electric heater or other types of heating units in the pump house.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) In the case of new installations, wellheads, well casings, pumps, pumping machinery, valve boxes connected with a suction pipe, or exposed suction pipes are not located in any pit, room, or space extending below ground level: *Provided,* That submersible pumps constructed to operate below the water level within the well casing may be installed on approval of the health officer.

(2) In the case of existing ground water supplies, such pits housing wellheads, well casings, pumps, pumping machinery, suction pipes, or valves connected with a suction pipe shall be accepted provisionally only if constructed or reconstructed in accordance with requirements of the State health department. It is recommended that provisionally accepted pits conform with the following minimum requirements as well as with any requirements set up by the State health department for their approval of specific installations:

(*a*) Pits shall be of watertight construction with walls extending at least 6 inches above the established ground surface at all points.

(*b*) Pits shall be provided with a watertight concrete floor sloping to a drain which discharges through a cast iron line not less than 4 inches in diameter to the ground surface at a lower elevation than the pit, and at least 30 feet from it; or if this is impossible, to a watertight concrete sump, in the pit, equipped with an automatic sump pump discharging through a steel or cast iron line to the ground surface at least 30 feet from the pit. [See item 12(B)].

(*c*) Pits shall be provided with a concrete base for pumps, or

pumping machinery, so that such units shall set at least 12 inches above the floor of the pit.

(*d*) Pits shall be provided with a satisfactory housing or cover in all cases.

ITEM 11. CONSTRUCTION AND INSTALLATION OF PUMPS

All water pumps shall be so constructed and installed as to prevent contamination of the water supply.

Public health reason.—Proper construction and installation of pumps is essential to prevent contamination from entering the well by means of the pump or pump mounting.

ITEM 11 (A). HAND PUMPS

Hand pumps may be mounted by setting the pump over the pipe sleeve and anchoring the base of the pump to the concrete pedestal or by mounting the base of the pump on a metal flange which is anchored rigidly to the pipe sleeve. The latter method of mounting a hand pump is preferable, inasmuch as this method provides a more permanent and rigid connection which is easily accessible when repairs are made. Hand pumps which are anchored to the concrete pedestal by means of nuts and bolts become loosened, resulting in an unsatisfactory installation. Where a hand pump is mounted on a flange, the pipe sleeve should extend at least 6 inches above the top of the concrete platform.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Hand pumps are of the force type with cylinders placed below or near the water level so that priming is not necessary.

(2) The pump base is watertight and of the solid one-piece recessed type, cast integrally with or threaded to the pump column or stand.

(3) The pump base is of sufficient diameter and depth to permit the well casing to extend not less than 1 inch into the base of the pump.

(4) The pump base is rigidly fastened to a metal flange by means of bolts and nuts, or by equivalent means.

(5) The pump head is of the closed type provided with a pump rod stuffing box.

(6) The pump spout is of the closed downward directed type.

(7) Suitable gaskets are used between the pump base and the flange to insure a watertight joint.

ITEM 11 (B). POWER PUMPS

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Any pump or power unit placed immediately over the well casing or pipe sleeve has a watertight metal base to form a cover for the well. The base plate is recessed on the underside to permit the casing or pipe sleeve to extend into it at least 1 inch above the level of the concrete foundation upon which the base of the pump or power unit rests, thus forming an overlapping cover with edges projecting below the top of the casing or pipe sleeve.

Where necessary the casing head can be enlarged or decreased in diameter by means of a pipe sleeve extension securely attached to the casing so as to be watertight. On flat base plates and other shapes where radial ribs interfere, a skirt projecting downward at least 1 inch below the top of the well casing may be welded to the outside edge of the base plate to form the overlapping cover for the well casing.

In installations having an open type pedestal for pump or power unit and having ample space to permit installation and removal of a watertight metal cover or of a lead packing or of a seal of sand and asphalt compound or cement grout, this type of closure may be used in lieu of the base plate type of cover, specified above, for the annular space between the suction pipe and the well casing. The well casing must extend at least 6 inches above the established ground surface at the well or the floor of the pump house, as required in paragraph (2) of item 5 of this manual.

(2) In the case of power pumps which are not placed directly over the well, the well casing extends at least 6 inches above the established ground surface at the well or the floor of the pump house and the annular space between the well casing and suction pipe is closed with a watertight cover or lead seal to prevent the entrance of contamination into the well.

(3) In case a submersible pump is installed within the well casing below the water level, the motor is enclosed completely in a water-

tight metal casing constructed to prevent oil from coming in contact with the water, and the oil is conveyed to the motor housing through noncorrodible heavy metal tubing.

(4) Any opening in the base plate of the pump or annular opening made by passing a pipe through the pump base is made watertight to a point above the spill line of the webbing around the plate. Such an opening may be threaded and a nipple extending above the spill line of the webbing screwed into it. The annular opening between the nipple and pipe passing through it may be leaded, fitted with a stuffing box and packing, or provided with an overlapping cover welded to the pipe. If there are any other openings in the base plate they are threaded and fitted with metal screw plugs.

(5) The pump or power unit base is anchored rigidly to the well casing or the pump platform.

(6) The discharge tee, check valve, and gate valve are located above the pump room floor.

(7) The discharge line from a power pump is provided with a sampling cock with the outlet terminating in a downward direction.

ITEM 12. PUMP HOUSE

The pump house shall be constructed properly to prevent flooding, shall be provided with adequate floor drainage, and if plumbing fixtures are to be provided they should be designed and installed properly.

ITEM 12 (A). CONSTRUCTION TO PREVENT FLOODING

Public health reason.—Proper construction of the pump house is essential to eliminate the possibility of the interior of the structure being flooded during emergencies.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) The pump house is provided with a doorway and a door at least 6 square feet in area which opens outward and extends to the floor.

(2) Pump houses located on side hill slopes have not less than 50 per cent of the floor area above ground level and the door located on that part of the floor above ground level.

ITEM 12 (B). DRAINAGE OF FLOORS

Public health reason.—A well-drained concrete floor promotes cleanliness and facilitates the removal of waste water.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) A floor drain is provided and is constructed of cast iron or equivalent material with an outlet not less than 4 inches in diameter.

(2) The inlet to the floor drain is located not less than 2 feet from the outer edge of the casing or pipe sleeve.

(3) A cast iron pipe line with watertight leaded joints is connected to the floor drain and carried to a point not less than 4 feet outside the building walls and connected to other suitable pipe which discharges onto the ground surface not less than 30 feet from the source: *Provided,* That where the drain line cannot be extended to the ground surface on a uniform grade toward the outlet, the line may discharge into an absorption pit located not less than 30 feet from the source. The drain line should be laid at a grade toward the outlet of not less than ⅛ inch per foot, except that for a floor drain installed for the purpose indicated and in the manner specified in this item (12 B), the requirements of item 3, "Distances to Sources of Contamination," shall not apply thereto. However, such drains shall not be connected to a storm or sanitary sewer; they may discharge to the ground surface or to a dry well which is well removed from contact with sewage or other wastes.

ITEM 12 (C). PLUMBING FIXTURES IN PUMP HOUSE

Public health reason.—Properly designed and installed plumbing fixtures will eliminate the public health hazard caused by the back siphonage of contaminated liquid wastes from faulty plumbing fixtures into the water supply piping.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Toilets, sewers, soil pipes, or drains are not located on the first floor directly above the pump room floor, or where leakage therefrom can reach any source of water supply or pump room.

(2) The locations of toilets, sewers, soil pipes, or drains in the

pump house are approved by the health officer, and the installation conforms to the requirements of item 3 of this manual, "Distances to Sources of Contamination."

(3) All plumbing fixtures comply with the Federal Specifications for Plumbing Fixtures, March 1940, WW-P-541a, or its equivalent. The requirements of these specifications with respect to air gaps and backflow preventers are strictly enforced.

ITEM 13. LUBRICATION OF PUMP BEARINGS

Pump bearings situated in any well below the pump room floor or platform shall be lubricated with water of a safe sanitary quality.

Public health reason.—Lubrication of pump bearings, situated in a well below the pump room floor, with oil, grease, or water other than of a safe sanitary quality may result in contamination of the water supply.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Pump bearings situated in any well below the pump room floor or platform are lubricated with water taken from within the well, or reservoir, or distribution system supplied with water from the original source of water supply, or from another supply which meets with the requirements of the health officer.

(2) In the case of existing installations using oil-lubricated bearings, the oil is stored and handled so as not to expose it to contamination.

ITEM 14. PRIMING OF POWER PUMPS

Priming type power pumps shall be primed with water of a safe sanitary quality applied from properly protected equipment.

Public health reason.—Priming of power pumps with water other than of a safe sanitary quality may result in contamination of the water supply as the result of priming water being forced into the distribution system.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Power pumps are primed with water taken from the original source for which the pump is used or from a reservoir or distribution

system supplied with water from the original sources of water supply or from another supply which meets the requirements of the health officer.

(2) Priming devices are so constructed and installed as not to expose the water to dust, drippings, or other sources of contamination.

ITEM 15. PROTECTION OF SUCTION PIPES

All subsurface suction piping leading from detached wells or reservoirs shall be protected adequately against the entrance of contamination.

Public health reason.—The suction created in the pipe line when water is pumped may result in contaminated ground water or surface water being drawn into the line through breaks or defective joints in the suction line.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) The pumps are placed directly over the well, sump, or reservoir wherever practicable, and the suction pipe, where located above ground, is in a frostproof box.

(2) In the case of a suction pipe rising to a pump house the outer casing extends not less than 6 inches above the platform or floor surface.

(3) The annular space between the protective casing pipe and the suction pipe is provided with a watertight seal at the top.

(4) Subsurface suction piping is not less than 10 feet below the ground, either natural or fill.

(5) All that part of any suction piping within 10 feet of and below the ground surface is surrounded by a watertight outer casing pipe or protected by equivalent means. In case of filled ground, an outer protective casing shall be used, regardless of depth of suction pipe.

Frequently the discharge lines of well pipes are under negative pressure. This is caused by water running back down into the well when the pump stops. These sections of pipe should be protected against contamination by methods similar to these recommended for suction pipes.

ITEM 16. VALVE BOXES

Every valve box on a buried suction pipe line shall be constructed and installed properly.

Public health reason.—Proper construction and installation of valve boxes are essential to prevent contaminated surface water from entering the valve box and accumulating around the valve. Valves submerged by surface water may result in contamination being drawn into the suction line through defective valves and connections.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Valves located on buried suction lines are protected with valve boxes which project not less than 6 inches above the floor if in a building or room, and not less than 12 inches above the ground surface if not enclosed in a building.

(2) The tops of all such valve boxes are provided with watertight overlapping covers.

(3) In case valves are installed on buried suction lines located 10 feet or more below the ground surface, the valve box is watertight for not less than 10 feet below the ground surface, and when the space between the valve box and the natural ground formations is filled with compacted puddled clay or equivalent materials.

(4) In case valves are installed on buried suction lines located less than 10 feet below the ground surface, the valve is enclosed completely in a watertight valve box. When valves cannot be enclosed completely in a valve box, the box shall be watertight and the opening between the base of the valve box and the valve dome or cover shall be sealed so as to be watertight.

Valves on buried suction lines should be avoided wherever possible by placing suction pipes above the pump room floor or above the ground surface.

ITEM 17. MANHOLES AND COVERS

Every manhole opening on spring structures, dug wells, or valve chambers shall be curbed above the adjoining surface and provided with an overlapping watertight cover.

Public health reason.—Manhole openings that are curbed and

provided with an overlapping watertight cover are essential to prevent contaminated surface water from entering the manhole opening.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) The manhole opening is curbed to a height of at least 6 inches above the adjoining surfaces.

(2) The manhole cover is watertight and overlaps the curbing and extends downward around it for not less than 2 inches.

(3) The manhole cover is kept in place by means of a hasp and lock, or by equivalent means.

(4) In case metal manhole covers are provided, the covers are welded, formed, or molded to form the overlap for the manhole opening and the metal shall be at least 12 gage.

ITEM 18. AIRLIFT SYSTEMS

The air compressor and appurtenances for any airlift system or mechanical aerating apparatus used in connection with a ground water supply shall be installed and operated properly.

Public health reason.—Proper construction, installation, and protection of air compressors and appurtenances is essential to prevent the entrance of insects, birds, or other contaminating materials, and to minimize the entrance of dust.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Watertight metal tubing, pipe, or equivalent materials are used for air intakes.

(2) The open end of an air intake of any airlift system or mechanical aerating apparatus is not less than 6 feet above the floor surface if indoors, 10 feet above the ground surface if outdoors, and 2 feet above a roof of a building through which it may project.

(3) The open end of the air intake is screened with 16-mesh brass or bronze screen, terminated in a downward direction, and an air filter installed in the intake line.

(4) The air compressor is located in a room as free as possible from dust and at such elevation that flooding of the equipment will be made impossible.

(5) The compressed air from the compressor is discharged into

an air storage tank, oil trap, or filter designed to remove from the compressed air oil or oil mist which may have entered during its passage through the compressor.

ITEM 19. CROSS-CONNECTIONS

There shall be no physical connection between a safe public ground water supply and any other water supply not of equal sanitary quality and under as rigid official supervision, and there shall be no connection or arrangement by which unsafe water may enter a safe public ground water supply system.

Public health reason.—This item is important, inasmuch as cross-connections have been found to be one of the principal causes of water-borne disease outbreaks. Wolman's and Gorman's figures show that during a 7-year period (1930-36) 14 reported water-borne outbreaks resulting in 139 cases of typhoid fever and 563 cases of diarrhea were due to cross-connections between safe and polluted water supply systems.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

There are no cross-connections, backflow connections, emergency intakes, bypasses,[1] or other arrangements by means of which polluted water or water of unknown or questionable quality may enter a safe public ground water supply system: *Provided,* That water of a safe sanitary quality may be supplied to any other system containing water of questionable quality only by means of an independent line discharging at least two pipe diameters and not less than 6 inches above the rim of storage units open to atmospheric pressure.

ITEM 20. BACTERIOLOGICAL, PHYSICAL, AND CHEMICAL QUALITY OF WATER

The bacteriological, physical, and chemical quality of water furnished to consumers from a public ground water supply shall be not less than the requirements of the Public Health Service[2] for drinking and culinary water used on common carriers operating in inter-

[1]These terms are defined in section 1 of this manual.
[2]Reprint No. 2440, Public Health Reports.

state commerce; when necessary, the water shall be treated to conform with the Public Health Service requirements.

Public health reason.—Diseases such as typhoid fever, cholera, dysentery, and other enteric diseases may be transmitted through the use of contaminated drinking water, and physiological disturbances may occur from the use of chemically or physically unsatisfactory water.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Untreated waters meet in all respects the requirements of this manual. Only those supplies meeting the bacteriological, physical, and chemical requirements of the United States Public Health Service Drinking Water Standards as shown by satisfactorily regular and frequent sanitary inspections and laboratory tests shall be approved for use without treatment.

(2) Public ground water supplies subject to a low degree of contamination (average coliform content of not more than 50 per 100 ml. in any month), but otherwise meeting all requirements of this manual, are given treatment consisting of chlorination and storage.

Chlorination facilities including equipment, control, and operating procedures shall be approved by the health officer. Free chlorine should be in contact with the treated water for not less than 20 minutes, or chloramine preferably for at least 3 hours before the treated water reaches the first consumer. Where necessary, baffle walls shall be used to prevent short-circuiting of the water from the inlet to the outlet of the detention reservoir so that the water will remain in the reservoir for the full flow-through period of time. The treated effluent shall meet the bacteriological requirements of the Public Health Service Drinking Water Standards.

Treatment shall be employed when there is a possibility of contamination reaching the water supply source and rendering it unsafe for domestic use. Treatment, however, should not be used permanently to overcome a defect of construction which can and should be corrected.

Where a treated underground supply is in use and an equally good untreated supply can be obtained, the treated supply shall be considered as temporary, to be used only until the untreated supply

can be made available. Treatment may then be used as an additional safeguard.

On a site where the earth formations permit the rapid movement of ground water, such as coarse gravel, fissured rock, solution channels, and similar formations, the ground water cannot be considered safe, and adequate treatment shall be provided.

(3) Treatment consisting of sedimentation, filtration, and disinfection is provided for waters containing numbers of coliform bacteria averaging over 50 per 100 ml. but not more than 5,000 per 100 ml. in any month and exceeding 5,000 per 100 ml. in not more than 20 per cent of the samples examined in any month.

Treatment processes, operation, and control for this class of water shall be approved by the State department of health. The treated effluent shall meet the bacteriological requirements of the Public Health Service Drinking Water Standards.

(4) Ground water supplies subjected to softening treatment or treatment for mineral removal employing various processes using chemicals in contact with the water, aeration, filtration, and similar methods are chlorinated before delivery for consumption.

ITEM 21. PLANT SUPERVISION AND CONTROL

All public ground water supplies shall be under the supervision and control of a competent operator.

Public health reason.—A competent operator is essential to prevent contamination of the water supply during reconstruction work, repair to equipment and appurtenances, or in the operation of the plant.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) All plants are under the supervision of a competent operator approved by the health officer, and in those States which have licensing requirements for waterworks operators, such requirements are met by the operator.

(2) In case of untreated ground water supplies, the operator is available on call in any emergency.

(3) In case the treatment of the water consists of chlorination

and storage only, the operator visits the plant not less than twice each day and is available on call in any emergency.

(4) In case additional treatment of the water supplements chlorination and storage, the supervision of the plant meets the requirements of the health officer.

(5) In case of treated ground water supplies, the operator keeps records essential to the control and operation of the plant and submits copies of such records as the health officer may require.

ITEM 22. WATER SAMPLING

Chemical analyses and bacteriological examinations of water samples and tests for residual chlorine shall be made by approved methods and at proper intervals.

Public health reason.—Chemical analyses and bacteriological examination of water samples and tests for residual chlorine are essential to guide the operator in running the plant and to determine whether the water is of satisfactory sanitary quality.

The recommended minimum intervals at which samples should be collected from all ground water supplies for bacteriological examination and residual chlorine tests are presented in the following tabulation:

Type of treatment	*Minimum interval of samplings for—*	
	Bacteriological examination[1]	*Residual chlorine tests*
None	1 month	
Chlorination and storage only	1 week	At least once in each successive 8-hour period.
Aeration, sedimentation, and filtration, or any combination thereof with chlorination and storage	Daily	Do.

In addition to bacteriological examinations and residual chlorine tests for underground water supplies requiring aeration, sedimentation, and filtration, or any combination thereof with chlorination and storage, the following laboratory tests should be made at frequent intervals where they are essential to control the treatment plant operation: temperature of air and water, turbidity, color, alkalinity, hydrogen-ion concentration (pH), and hardness. Occasionally special

[1]The number of bacteriological samples to be collected from the distribution system per month should be in accordance with the requirements of the Public Health Service Drinking Water Standards as indicated in Figure 1.

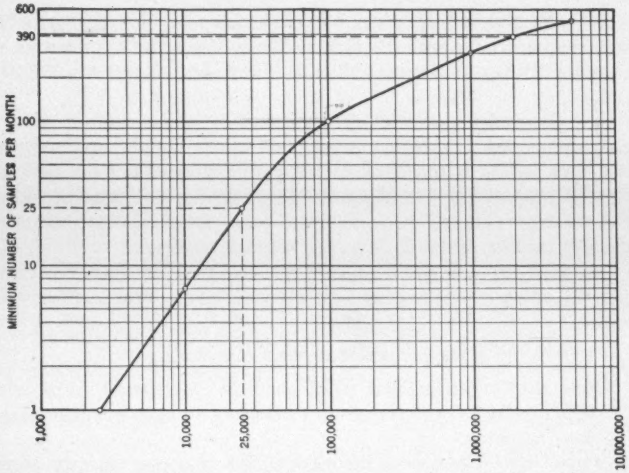

FIGURE 1

tests may be necessary such as for residual alum, iron, manganese, or other undesirable constituents of the final effluent. Where prechlorination is used in addition to postchlorination, tests for residual chlorine should be made at each major stage of treatment, and, in the raw water, test for chlorine demand.

For operational control at the plant, the frequency of tests, particularly for turbidity, residual chlorine, bacterial count, and coliform organisms, though dependent on the character of water treated and on its variability, should be such that at least one test each 24 hours and every day of the week will be carried out For the larger plants, at least three sets of samples are usually collected daily for bacteriological tests. Determinations of turbidity and residual chlorine are made more frequently, sometimes at hourly intervals when the character of the raw or partly treated water is changing rapidly.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) All physical, chemical, bacteriological, and biological tests are made in conformity with "Standard Methods for the examination of Water and Sewage," *American Public Health Association*, 8th Edition 1936.

(2) Bacteriological and chemical tests of water samples from a newly developed or constructed ground water supply are made at least once following disinfection. The supply shall not be used for domestic purposes, where adequate treatment has not been provided, until the report on the bacteriological examination of water samples indicates that the water is of a safe sanitary quality.

(3) All ground water supplies are sampled for bacteriological, chemical, and physical tests at such intervals as the health officer may require.

ITEM 23. ABANDONMENT OF WELLS

Permanently abandoned wells shall be adequately filled with selected material to protect the water-bearing formation against possible contamination.

Public health reason.—Adequate filling of a permanently abandoned well is essential to prevent contamination from being introduced into the water-bearing formation through an abandoned well, which may result in contamination of existing or future ground water supplies in the vicinity.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Drilled or cased wells are filled completely with neat cement grout, concrete, or clean puddled clay.

(2) Driven wells are filled completely with neat cement grout, concrete, or clean puddled clay.

(3) Dug or bored wells are filled completely with puddled clay or its equal after as much as possible of the curbing is removed.

ITEM 24. DISTRIBUTION

The distribution system shall be designed and constructed so as to prevent leakage of water due to defective materials, improper jointing, corrosion, settling, impacts, freezing, or other causes. Adequate valves and blow-offs, properly installed, shall be provided so that

necessary repairs can be made with a minimum interruption of service.

Public health reason.—Proper design and construction of the distribution system are necessary in order to deliver a safe water, to guard against contamination of water in the mains from outside sources, and to prevent leakage under conditions of decrease in pressure or negative pressure, and during repairs, break-downs, and installation of new mains.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Cast iron water mains are laid in accordance with the "Specifications for Laying Cast Iron Pipe," adopted by the American Water Works Association (see *Journal of the American Water Works Association*, Vol. 30, No. 2, February 1938).

(2) Trenching operations are conducted so that the contents of sewers and drains do not enter the trench.

Measures should be taken to prevent defecation and urination in the trench. Suitable sanitary conveniences should be provided for the workmen, and wherever practicable such sanitary facilities should be connected to the sewers. Proper trench drainage should be provided and the end of the pipe should be kept closed except when joints are being made.

(3) Newly laid pipe lines, before covering, are tested under a hydrostatic pressure 50 per cent in excess of the normal operating pressure after expelling all air from the pipe. The duration of each pressure test shall be at least 30 minutes.

All exposed pipes, fittings, valves, hydrants, and joints should be carefully examined during the open trench test. All joints made with lead showing visible leakage should be recaulked until tight. Where the joints are made with sulfur compound or with cement and show seepage or slight leakage only such joints as may be defective should be cut out and replaced. Any cracked or defective pipes, fittings, valves, or hydrants discovered in consequence of this pressure test should be removed and replaced with sound material, and the test should be repeated until the pipe installation is satisfactory.

Suitable means should be provided for determining the quantity of water lost by leakage under normal operating pressure. No pipe installation should be accepted until or unless this leakage (evaluated

on a pressure basis of 150 pounds per square inch) is less than 100 gallons per 24 hours per mile of pipe per inch nominal diameter for pipe in 12-foot lengths, 75 gallons for 16-foot lengths, and correspondingly varied for other lengths of pipe. In calculating leakage, allowance should be made for added joints in the pipe line above those incidental to normal unit lengths of pipe.

(4) Jointing materials are free from oil, tar, or greasy substances, are disinfected before use, examined bacteriologically after disinfection for freedom from coliform organisms, kept free from contamination, and applied dry; and when jointing materials will produce watertight joints, under all conditions to which the joint will be subjected.

(5) Water pipes are not laid in water, or where they can be flooded with water or sewage in laying, wherever this is practicable. When necessary to lay water lines below the water table or in wet ground, additional protection shall be provided for the joints, to insure watertightness, to the satisfaction of the health officer.

(6) Water mains crossing or laid near railroad tracks are constructed so that the pipe joints have a reasonable degree of flexibility and remain watertight.

The pipe line should be of such strength and tightness as to remain watertight under the loading and vibrations to which it will be subjected. Mechanical joints with rubber gaskets are suitable for such conditions. It is advisable in such situations to consult the railroad company and obtain approval for the crossing in advance of construction work.

(7) Laying of water pipes under water or under the bed of a stream is avoided and the crossing made on bridges, dams, or other structures sufficiently elevated so that the pipe will not be subject to immersion at any time, whenever this construction can be provided.

Above water crossings:

In cases where it is practicable to secure a satisfactory overhead crossing, particularly on bridges, consideration shall be given to the following items:

(*a*) The use of flexible pipe joints to maintain tightness under forces due to vibration and temperature variations and to prevent

breaks and leaks at the points where the mains make sharp bends in leaving and returning to the ground.

(*b*) Protection of pipe from impact of runaway vehicles.

(*c*) Protection of pipe from flood waters or objects carried by flood waters.

Under water crossings:

In special cases where it is impossible or impractical to secure a satisfactory overhead crossing special construction to provide additional safeguards is necessary. These safeguards are briefly as follows:

(*a*) The pipe should not be laid on the stream bed or in the body of water. If an under crossing is made, it should be placed sufficiently far below the bottom of the body of water to protect the pipe against freezing and being moved by currents, ice, floating objects, anchors, dredges, or being otherwise disturbed. The distance below the stream bed should not be less than 5 feet.

(*b*) The pipe should be of special construction having flexible watertight joints.

(*c*) All pipe lines in under-water crossings should be provided with valves at both ends of the crossing so that the section can be isolated. The valves should be so located that they will not be subject to flooding.

(*d*) Permanent equipment should be installed for making periodic or continuous pressure tests for detecting leakage of the crossing.

(*e*) Sampling taps should be installed at each end of the crossing for the collection of samples for bacteriological examination.

(*f*) Provision should be made to blow off such sections of pipe to waste above ground level.

(*g*) Consideration should be given to the construction of under-water crossings in duplicate in order that continuous service and adequate pressure may better be maintained. Properly drained pipe tunnels deserve consideration because they facilitate inspection, repairs, and detection of leaks.

(8) Water lines are laid in trenches separated by at least 10 feet of solid earth from sewer lines.

(9) Water pipes are laid, so far as possible, above the elevation of nearby sewers and at least 10 feet laterally from them. Where this requirement cannot be met because of physical conditions, extra

precautions are taken in securing absolute and permanent tightness of water pipe joints.

(10) Newly installed water mains are flushed thoroughly to waste through hydrants or other approved means to remove all dirt and foreign matter. The mains are disinfected in accordance with the following procedure and bacteriological tests indicate that the water conforms with the bacteriological requirements of the United States Public Health Service Drinking Water Standards before water conveyed in the mains is used for domestic consumption.

Disinfection procedure:

After flushing the mains, introduce chlorine and water so that the mixture of water and chlorine entering the pipe shall contain a chlorine concentration of at least 50 p.p.m. Retain treated water in the pipes long enough to destroy all nonsporeforming bacteria. The period of detention should be at least 3 hours and preferably longer. After the chlorine-treated water has been retained for the required time the chlorine residual at pipe extremities and at other representative points should be at least 5 p.p.m. If the residual is less than 5 p.p.m., the procedure should be repeated until a 5 p.p.m. residual is obtained. Upon completion of the disinfection process the water containing residual chlorine should be flushed from the system of pipes under treatment and water samples collected for the bacteriological examination mentioned above.

(11) All new plumbing is installed in accordance with the provisions of the State plumbing code and all existing plumbing which is not properly designed or properly installed, or both, is changed to conform with the State plumbing code as soon as the opportunity to do so presents itself.

Where State plumbing codes are not in effect the provisions of the "Plumbing Manual," Report BMS 66, issued by the National Bureau of Standards, should be followed. During the war emergency use of substitute materials for critical items required in BMS 66 will be permitted in accordance with requirements of the War Production Board.

(12) The water service pipe is watertight and corrosion-resistant. Copper pipe and cast iron pipe with specially protected joints such as cast-iron pipe with bell joint clamps are recommended.

Where a water service pipe crosses a street sewer at less than 6

feet vertically above the sewer, or is within 10 feet of it horizontally, all that part of the water pipe lying within these distances should be constructed preferably of copper or brass pipe connected to the iron pipe with a brass fitting. In such cases it is preferable to use copper or brass pipe from the water main to the house, and the house sewers should be constructed of extra heavy cast iron with watertight joints. (During the war emergency where priorities necessitate the use of materials other than brass or copper, extra heavy iron pipe should be used under these conditions.)

(13) The handling, repairing, testing, and installation of water meters are carried out in such a manner as to prevent introduction of contamination into the water supply system.

Before meters are installed they should be disinfected unless they are disinfected together with adjacent pipe before the system is placed in service. If meters are disinfected some considerable time before they are placed in the pipe line, the inlets and outlets should be capped to prevent the entrance of dirt, dust, or other contaminating material. Meters may be disinfected by passing a solution of chlorine of about 50 p.p.m. strength into the meter and keeping it in contact with the parts for at least 5 minutes.

(14) Hydrant drains are not connected to sanitary or storm sewers but are connected to dry wells or drain to the surface of the ground. Wherever practical, the hydrant drain should be plugged and arrangements made to pump out the hydrants after use.

(15) Chambers or pits containing gate valves, air relief valves, blowoffs, or other such appurtenances to a distribution system are not connected directly to any sanitary or storm sewer, and blow-offs are not connected directly to any sewer.

(16) Booster stations on the distribution system are located in rooms that have floors above ground level and are so designed and located that they will not cause a negative head in the distribution piping. In some cases it may be necessary to provide a receiving reservoir from which the water can be drawn instead of drawing suction directly from the mains.

(17) In case it is necessary to supply water from the mains of a water system that is known to be safe to some other system which is unsafe, the water is delivered through a pipe to a tank or reservoir

connected to the unsafe system in accordance with the provisions of item 19 of this manual.

(18) The piping system is designed and installed to maintain a positive pressure in all its parts under normal usage at all times.

(19) The system is designed so as to afford effective circulation of water with a minimum of dead ends.

ITEM 25. STORAGE

All reservoirs and storage tanks shall be of sanitary and watertight construction and made of concrete, steel, wood, or other materials approved by the health officer: *Provided,* That wood shall not be used for reservoirs or storage tanks located wholly or partly underground. Reservoirs and storage tanks shall be located at safe distances from sources of contamination.

Public health reason.—Water which is safe and of approved quality at the source may be contaminated in storage units unless precautions are taken to prevent entry of shallow ground water, surface flood waters, or other pollution.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Ground water storage units are watertight. When such units are made of concrete they shall be adequately reinforced to prevent development of cracks; where construction joints are necessary, adequate water stops, approved by the health officer, shall be installed. If such units are made of steel they shall be protected against corrosion. Painting[3] of steel tanks usually affords protection from corrosion for a number of years. Cathodic protection is another method used for corrosin protection of metal tanks.

(2) All such water storage units are located at satisfactory distances from sources of contamination. In ascertaining such safe distances the requirements of item 3 of this manual shall be followed.

(3) All such water storage units are equipped with watertight covers, and manhole openings in such covers comply with the requirement of item 17 of this manual.

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[3]Tentative Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs. J. Am. Water Works Assoc., 32:39-42, (December 1940).

(4) All such ground water storage units are located and protected so that there is no danger of contamination by surface drainage or flooding.

(5) Air vents in storage units are constructed of metal tubing or pipe connected so as to be watertight, and the open end of the vent is screened with 16-mesh brass or bronze screen and terminated in a downward direction by means of an elbow or equivalent means and the lower end of the outlet is not less than 12 inches above the roof of the storage unit, nor less than 24 inches above the established ground elevation.

(6) Overflows and water-level control gages are constructed so as to prevent the entrance of birds, insects, or contaminating materials, and when all openings are screened with 16-mesh brass or bronze screen and hooded or otherwise protected to prevent contaminating material from entering the opening.

(7) Overflows, blowoffs, or clean-out pipes, and drains from the roof or bottom of storage units are not directly connected to sewers.

Such pipes may discharge onto ground surface or into an open receptacle from a point at least 6 inches above the rim of the receptacle. The receptacle should be situated at ground surface and at least 50 feet from the reservoir and may be connected to sewers.

(8) Storage units are located so that traffic will not pass over them.

(9) New reservoirs or tanks or such units which have been contaminated or subjected to the possibility of contamination as during cleaning, alteration, painting, or repairing operations are disinfected before water from them is used for domestic consumption. The following procedure, recommended by the Minnesota Department of Health, is suggested as a satisfactory method of disinfection:

The underside of the roof should be washed down even though it is normally in contact with the water. Since only the floor and walls are in contact with the water these parts shoud be given special attention. A given amount of chlorine is more effective if applied in concentrated solution to the walls and floor of the reservoir or tank with a brush or spray than if placed in a tank full of water.

Scattering dry powdered chlorinated lime onto the walls and the floor of the reservoir when it is empty and then filling it with water to the overflow is also fairly effective. Where a chlorine solution of high concentration (100 p.p.m.) is used on the walls and floor, it should be rinsed off by washing down the walls and the floor with a stream of water, and this water wasted. Any adjacent valves

on pipe lines connected to the reservoir should be operated so as to bring the chlorine solution to all parts that come in contact with water in the pipe. When this has been done sufficient chlorinated lime should be placed in the reservoir to produce a residual of at least 1.0 p.p.m. at the end of a 3-hour holding period. The reservoir should then be filled with water to the overflow. After the treated water is held in the reservoir for at least 3 hours it may be turned into the distribution system. One part per million for 100,000 gallons of water will require 1.25 pounds of chlorinated lime of 66 per cent available chlorine.

Reservoirs should always be disinfected after they have been altered, painted, or repaired. When the contamination is known to be limited, the disinfection may be accomplished by adding the chlorine to the reservoir full of water. The water may then be used in the distribution system.

Reservoirs may be utilized in providing large volumes of chlorinated water for the purpose of disinfecting the pipe lines of the distribution system or parts of it.

For disinfecting purposes pressure tanks should be provided with an air-relief valve and an overflow on the top so that all air can be expelled from the tank and the entire surface of the interior brought into contact with water containing a high residual of chlorine.

ITEM 26. PROTECTION DURING CONSTRUCTION

All public ground water supply systems which are hereafter constructed, reconstructed, or extensively altered shall be adequately protected to prevent contamination of water at the source or in the system during construction.

Public health reason.—The diversion of surface water away from the source and the use of water of a safe sanitary quality during construction is essential to prevent contamination of the ground water supply.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) All surface water is properly diverted away from the source during construction.

(2) All water used for construction is obtained from a known safe source, or adequately disinfected.

ITEM 27. DISINFECTION AFTER CONSTRUCTION AND REPAIR

Underground water supplies shall always be disinfected following new construction or repair work, to remove all traces of contamination.

Public health reason.—Water from newly developed ground water

supplies and existing supplies which have been subjected to changes and repairs often shows an unsatisfactory sanitary quality as indicated by bacteriological examination of samples collected from the source. This is usually due to contamination from workmen, equipment, materials, or surface water which may be introduced into the ground water supply during the process of construction or repair work. While such contamination may not always be serious in itself, it obscures the meaning of the bacteriological test when present.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) All new construction and repair work is disinfected with a chlorine solution containing not less than 50 p.p.m. of available chlorine: *Provided,* That where minor repairs are made to existing ground water supplies and adequate treatment of the water is provided beyond the point where repairs are made, disinfection shall not be mandatory.

(2) Not less than 5 p.p.m. of residual chlorine is present at the source and at other representative points which have been in contact with the chlorine solution for a period of at least 3 hours, and preferably 10 hours or longer: *Provided,* That in the case of flowing springs and flowing wells this requirement shall not be mandatory. (See appendix B, Flowing Wells and Flowing Springs.)

(3) The system is thoroughly pumped or otherwise thoroughly flushed to remove all traces of chlorine after disinfection.

(4) The results of bacteriological examination of water samples collected after disinfection and flushing of newly developed ground water supplies show that all traces of contamination have been eliminated. Such tests shall be repeated at least once after the system is shown to be clean, to check on possible regrowths.

Refer to appendix B for recommended procedure for disinfection of springs and wells.

ITEM 28. ROTTLED WATERS

All bottled waters shall be so handled, from source to ultimate user, as to prevent contamination of such ground waters originally obtained from approved sources.

The provisions of this item shall not be interpreted as applying to

carbonated waters, artificially prepared mineral waters, soft drinks, or similar beverages, but only to public ground water supplies, as defined in section 1, which are put into bottles or containers for the use of consumers: *Provided,* That the requirements of this item shall not be interpreted as replacing any provision of the Federal Food, Drug, and Cosmetic Act applying to beverages.

Public health reason.—Contamination of originally safe ground water supplies may occur in the processes of bottling, capping, handling, and reuse of containers. Therefore, special precautions should be taken to prevent such contamination.

Satisfactory compliance.—This item shall be deemed to have been satisfied when:

(1) Ground water sources used for bottling conform with the sanitation items for approved public ground water supplies given in this manual.

(2) Bottling is accomplished in a separate room equipped and used for this operation only.

(3) Bottling, capping, handling, and reuse of containers is carried out in such a manner that the final product ready for distribution in the container shall comply with the requirements of item 20 of this manual.

Specimens of bottled water collected for bacteriological analysis to determine compliance with this requirement should be taken at various places, including bottles in transit on delivery trucks, railroad cars, etc., to check on handling procedures and effectiveness of bottle washing.

APPENDIX A

Recommended Procedure for Cement Grouting of Wells for Sanitary Protection[1]

The annular space between the well casing and the well hole is one of the principal avenues through which undesirable water and pollutional matter may gain access to a well. The most satisfactory way of eliminating this hazard is to fill the annular space with cement

[1]This information has been taken principally from a pamphlet of the Wisconsin State Board of Health entitled: "Methods of Cement Grouting for Sanitary Protection of Wells." The subject is discussed in greater detail in that publication.

grout. To accomplish this satisfactorily, careful attention should be given to see that:

(1) The grout mixture is properly prepared.

(2) The grout material is placed in one continuous mass.

(3) The grout material is placed upward from the bottom of the space to be grouted.

Concrete grout should be a mixture of cement, sand, and water in the proportion of 1 bag of cement (94 pounds), an equal volume of dry sand, and 5 to 6 gallons of clean water.

Neat cement grout should be a mixture of cement and water in the proportion of 1 bag of cement (94 pounds) and 5 to 6 gallons of clean water. Whenever possible, water content should be kept near the lower limit given. Hydrated lime to the extent of 10 per cent of the volume of cement may be added to make the grout mix more fluid and thereby facilitate placement by the pumping equipment. Mixing of cement or cement and hydrated lime with the water must be thorough.

Grouting procedure.—The grout mixture must be placed in one continuous mass; before starting the operation, sufficient materials should be on hand and other facilities available to accomplish the placement without interruption.

Restricted passages will result in clogging and failure to complete the grouting operation. The minimum clearance at any point, including couplings, should not be less than 1½ inches. When grouting through the annular space, the grout pipe should not be less than 1 inch nominal diameter. As the grout moves upward, it picks up much loose material such as results from caving. Accordingly, it is desirable to waste a suitable quantity of the grout which first emerges from the drill hole.

In grouting a well so that the material moves upward, there are two general procedures that may be followed: (1) The grout pipe may be installed within the well casing, or (2) in the annular space between the casing and drill hole, when there is sufficient clearance to permit this. In the latter case, the grout pipe is installed in the annular space to within a few inches of the bottom of the annular space. The grout is pumped through this pipe, discharging into the annular space, and moving upward, around the casing pipe, finally over-

flowing at the ground surface. In 3 to 7 days the grout will be set, and the well van be completed and pumping started.

When the grout pipe is installed within the well casing, the casing should be supported a few inches above the bottom during grouting, to permit grout to flow into the annular space. The well casing is fitted at the bottom with a cap threaded to receive the grout pipe and a check valve to prevent return of grout into the casing pipe. After grout appears at the surface, the casing pipe is lowered to the bottom, grout pipe unscrewed immediately and raised a few inches. A suitable quantity of water should then be pumped through it, thereby flushing any remaining grout from it and the casing pipe. The grout pipe is then removed from the well, and 3 to 7 days are allowed for setting of the grout. The well is then cleared by drilling out the cap, check valve, plug, and grout remaining within the well.

A modification of this procedure is the use of the well casing itself to convey the grout to the annular space. The casing pipe is suspended in the drill hole and held several feet off the bottom. A "spacer" is inserted in the casing pipe. The casing pipe is then capped and connection made from it to the grout pump. The estimated quantity of grout, including a suitable allowance for filling of crevices and other voids, is then pumped into the casing pipe. The spacer moves before the grout, in turn forcing the water in the well ahead of it. Arriving at the lower casing terminal, the spacer is forced to the bottom of the drill hole, leaving sufficient clearance to permit flow of grout into the annular space and upward through it.

After the desired amount of grout has been pumped into the casing pipe, the cap is removed, and a second spacer is inserted in the casing pipe. The cap is then replaced and a measured volume of water, sufficient to fill all lbut a few feet of the casing pipe, is pumped into it. Thus all but a small quantity of the grout is forced from the casing pipe into the annular space. From 3 to 7 days are allowed for setting of the grout. The spacers and grout remaining in the casing and drill hole are then drilled out and the well completed.

When the annular space is to be grouted for only part of the total depth of the well, the grouting can be carried out as directed above when the well reaches the desired depth, and the well then continued below this level, within the first casing. In this type of construction,

where various-sized casings "telescope" within each other, a seal should be placed at the point of transition or "telescoping" in the annular space between the two casing pipes of different diameters. The annular space for grouting between two metal casings should be not less than 1½ inches and the depth of the seal not less than 8 feet.

APPENDIX B

Recommended Procedure for Disinfection of Wells, Springs, and Appurtenances

An effective and economical method of disinfecting wells, springs, and appurtenances is by the use of calcium hypochlorite (chlorinated lime) containing approximately 25 per cent available chlorine. This material can be purchased at most drug stores and in larger quantities at chemical supply houses; a fresh supply should be used, since the chemical deteriorates on exposure to the atmosphere. If commercial preparations of high-test calcium hypochlorite containing approximately 70 per cent available chlorine are used, the required dosage will be about one-third the amount of chlorinated lime specified below.

To the amount of chlorinated lime specified in Table 1, add small quantities of water slowly and stir until a smooth, watery paste free from lumps has been formed. Add from 5 to 20 gallons of water to the paste, and stir thoroughly from 10 to 15 minutes prior to allowing the solution to settle. The clearer liquid containing the chlorine should be used, and the inert material or lime that has settled to the bottom of the container discarded. The solution should be prepared in a thoroughly cleaned utensil; the use of metal containers should be avoided, if possible, since they are corroded by strong chlorine solutions.

Where small quantities of chlorinated lime are required and a scale is not available, the material can be measured with a spoon. A moderately heaping tablespoonful of chlorinated lime, that is, with the powder about 1 inch deep in the center, weighs approximately 1 ounce.

Spring basins.—(1) Wash the interior walls of the spring basin with a solution of chlorinated lime, using a stiff broom or brush to assure thorough cleaning, prior to placing the cover over the structure.

(2) Where a manhole opening is not provided in the cover, the proper amount of chlorinated lime solution should be poured into the

TABLE 1.—*Liquid capacity of wells or spring structures and the amounts of chlorinated lime required to provide a dosage of approximately 50 parts per million of available chlorine*

Capacity of well or springs in gallons	Chlorinated lime required, in ounces	Approximate volume of water, in gallons, to be used in preparing chlorine solution
50	1.5	5
100	3.0	5
200	6.0	5
300	9.0	5
400	12.0	5
500	15.0	5
1,000	30.0	10
2,000	60.0	15
3,000	90.00	20

basin and mixed with the water just before placing the cover over the structure. Care should be taken in placing the cover in position to prevent any extraneous material from entering the basin.

(3) Where a manhole is provided in the cover of the spring basin, the proper amount of chlorinated lime should be poured into the basin through the manhole opening and mixed with the water just before placing the cover over the manhole.

Shallow wells.—(1) After the casing or lining is completed, proceed as outlined below before the cover platform is placed over the well.

(*a*) Remove all equipment and materials including tools, forms, platforms, etc., which will not form a permanent part of the completed structure.

(*b*) Wash the interior walls of the casing or lining with a solution of chlorinated lime, using a stiff broom or brush to assure thorough cleaning.

(*c*) Pump the water from the well until it is perfectly clear, and remove the pumping equipment that was temporarily set up for this purpose.

(2) Place the cover over the well, and pour the required amount of chlorinated lime solution into the well through the manhole or pipe sleeve opening just prior to inserting the pump cylinder and drop pipe assembly. Care should be taken to distribute the chlorine solution over as much of the surface of the water as possible to obtain proper diffusion of the chemical with the well water.

(3) Wash the exterior surface of the pump cylinder and drop pipe with the chlorinated lime solution as the assembly is being lowered into the well.

(4) After the pump has been set in position, pump water from the well until a strong odor of chlorine is noted.

(5) Allow the chlorine solution to remain in the well for not less than 10 hours.

(6) After not less than 10 hours has elapsed, the well should be flushed by pumping the water to waste to remove all traces of chlorine.

Drilled and bored wells, flowing wells, and flowing springs.—(1) When the well is being tested for yield, the test pump should be operated until the well water is as clear and free from turbidity as possible.

(2) After the testing equipment has been removed, pour the required amount of chlorinated lime solution into the well slowly just prior to installing the permanent pumping equipment. Diffusion of the chemical with the well water may be facilitated by running the solution into the well through a hose or pipe line as the line is being alternately raised and lowered, and this method should be followed whenever possible.

(3) Wash the exterior surfaces of the pump cylinder and drop pipe with a chlorinated lime solution as the assembly is being lowered into the well.

(4) After the pump has been set in position, operate the pump until water discharged to waste has a distinct odor of chlorine. Repeat this procedure a few times after intervals of about 1 hour.

(5) When the chlorine solution has been completely circulated through the column of water in the well and the pumping equipment, allow the chlorine solution to remain in the well for not less than 10 hours.

(6) After not less than 10 hours have elapsed, the well should be flushed by pumping the water to waste to remove all traces of chlorine. The pump should be operated until water discharged to waste is free from the odor of chlorine.

In the case of deep wells having a high water level, it may be necessary to resort to special methods of introducing the disinfecting agent into the well so as to insure proper diffusion of chlorine through-

out the well. A method readily available is to place chlorinated lime or high test granulated calcium hypochlorite in a short section of pipe capped at both ends. A number of small holes should be drilled through each cap and one of the caps fitted with an eye to facilitate attachment of a suitable cable. The disinfecting agent is distributed by lowering and raising the pipe section throughout the depth of the water. In the case of flowing wells and flowing springs, the pipe section should be moved up and down near the bottom of the well or spring. The water moving upward through the well or spring will carry with it the disinfecting agent released at the bottom. It is impractical to maintain chlorine in flowing wells and springs for 10 hours as specified in paragraph (5) above. Sufficient chlorine, therefore, should be applied to maintain a chlorine residual of 50 p.p.m. in the water flowing from the well or spring for at least 20 minutes. If bacteriological results on water samples collected after all traces of chlorine have disappeared indicate that the water is not safe to use, the disinfection procedure should be repeated until satisfactory results are obtained or else the supply should be chlorinated continuously or abandoned.

Sometimes an existing well is encountered which does not respond to the usual methods of sterilization. Usually a well like this has been polluted by water which entered the well under sufficient head to cause a flow of water from the well into the water-bearing formation, carrying the pollution with it. To reach the bacteria which have thus been carried into the water-bearing formation, it is necessary to force chlorine into the formation. This may be done in a number of ways, depending on the construction of the well. In some wells, it is advisable to chlorinate the water in the well and then add a considerable volume of chlorinated water in order to force the treated water into the formation. In other wells, such as the drilled well cased with standard weight casing pipe, it is entirely practicable to chlorinate the water in the well, then cap the well and apply a head of air. By alternately applying and releasing the air, a vigorous surging effect is obtained, and chlorinated water is forced into the water-bearing formation. After treating a well in this manner it is necessary, of course, to flush it to remove the chlorine.

Should the reports on the bacteriological examination of water

samples be unsatisfactory after disinfection, it would indicate that the initial treatment was ineffective. In this case, the procedure should be repeated until tests show that water samples from that portion of the system being disinfected are satisfactory from a bacteriological standpoint.

The water from the system should not be used for domestic and culinary purposes until the report on the bacteriological examination of water samples indicates that the water is safe for domestic use.

PROCEEDINGS

FEBRUARY 1945 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, February 15, 1945

Vice-President Harold W. Griswold in the chair.

ARTHUR L. SHAW reported the following election to membership: Frank J. Driscoll, Superintendent, Chicopee, Mass.; James E. Kenney, Water Board, Holyoke, Mass.; Ralph M. Legette, Consulting Geologist, New York, N. Y.; N. T. Veatch, Consulting Engineer, Kansas City, Mo.; Joseph O'Hanlon, Boston Water Division, Dorchester, Mass.; J. V. McDermott, Flexible Sewer Rod Equipment, Roslindale, Mass.; and Raymond F. Goudey, Sanitary Engineer, Department of Water and Sewers, Los Angeles, Cal.

A film in connection with the 1945 Red Cross Fund was shown, and Mr. Arthur Lynch of the Boston Consolidated Gas Company gave an interesting talk about the matter.

A paper, "Recent Survey of Interior Water Piping in Connecticut," was read by David C. Wiggin, Sanitary Engineer, Connecticut State Department of Health.

A paper, "Responsibility for Water Piping on Consumer Premises," was read by Warren J. Scott, Director, Bureau of Sanitary Engineering, Connecticut State Department of Health.

Arthur D. Weston, Chief Engineer, Massachusetts State Department of Health, discussed the general subject covered by the papers.

MARCH 1945 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, March 15, 1945

President Karl R. Kennison in the Chair.

In the absence of Secretary Gifford, ARTHUR L. SHAW reported the following elections to membership:

Harry Mortimer Freeburn, Chief Engineer, Philadelphia Suburban Water Company, Bryn Mawr, Pa.; John R. Kaye, Partner, Engineering Service Co., Halifax, N. S.; DeVer C. Warner, Vice-President and Treasurer, Bridgeport Hydraulic Co., Bridgeport, Conn.; Edward V. O'Donnell, Foreman, Water Department, Gardner, Mass.; Joseph W. Gerniglia, Senior Sanitary Aide, Metropolitan District Commission, Water Division, Somerville, Mass.; Harvey W. L. Doane, Public Utilities Commission, Halifax, N. S.

On motion of Harry U. Fuller, duly seconded, it was VOTED that the President appoint a Committee to nominate officers for the ensuing year.

Chairman King of the Legislative Committee made a report on a number of bills pending before the Massachusetts Legislature.

A paper, Real Estate Acquisitions for Metropolitan Boston's Water Supply in the Swift River and Ware River Watersheds—Supplement," was read by James A. Christenson, Civil Engineer, Boston, Mass., formerly with the Metropolitan District Water Supply Commission.

A paper, "Factors Influencing the Corrosion of Copper and Copper Base Alloys by Fresh Waters," was read by C. L. Bulow, Research Chemist, Bridgeport Brass Co., Bridgeport, Conn.

Some U. S. Army films were shown.

BOOK REVIEW

Methods of Climatology. By Victor A. Conrad. xx+228 pp. Cambridge, Mass.: Harvard University Press, 1944. $4.00.

As an inhabitant of the bottom of a sea of air which is many times deeper than any ocean, man has long been aware that climate is the major element of the natural equipment of a region. By itself and in its direct effect upon vegetation, soil and drainage characteristics, climate is the single most important factor that establishes the potentialities of the various regions of the earth's surface. Accordingly a lively interest in climate has been manifest ever since the world-wide expansion of European civilization at the close of the Middle Ages. The accumulated resources of investigation of generations of travellers and observers have evolved into the science of climatology. Development of atmospheric science has been accelerated enormously in the past two decades with the advent of aviation. Today under the lash of war the stimulus has been increased greatly, not only with respect to the need for faster, more reliable weather predictions but also with the need of successful global military strategy for climatological knowledge of countries and regions of peoples and races. It is the purpose of Dr. Conrad's book to demonstrate how climatological investigations may be analyzed critically and scientifically so as to produce a quantitative description of climate.

The book presents a much needed, concise methodological treatment of a science that has only recently entered a mature phase of quantitative development. Progress in climatology, it is significant to note, has been along unique lines. Many scientists and engineers have a working knowledge of climatological results, but do not know how to deal with the original data of observations. In most fields conversancy with results connotes familiarity with methods of establishing results. It is hoped that the book will overcome this disparity and serve to bridge the gap between a knowledge of the results themselves and the ways of getting them.

The book sets forth the methods of mathematical statistics and

theory of probability that are immediately applicable to climatological problems. In a thoroughly practical treatment the author makes an unblushing use of approximations. He manifestly attaches a higher order of importance to an uninterrupted factual treatment of the subject matter than to developing in rigorous detail the sundry tantalizing mathematical by-paths that appear. Nevertheless, for the student interested in mathematical proofs and the philosophical background, ample references are given to the technical literature.

The book is organized along the following lines:

Part I—General Methods. Climatology as a world science; the meteorological register; climatological observations. Statistical characteristics of climatological elements; curve-fitting; harmonic analysis.

Part II—Representation of Characteristic Elements. An elaboration upon methods of handling raw data and deriving the descriptive statistical parameters of certain important and less well known characteristics, such as for temperature, atmospheric pressure, wind, cloudiness and precipitation.

Part III—Method of Spatial Comparison. Geographical distribution of climatological elements; graphical comparison; method of anomalies. A brief discussion only is given of air mass climatology and theories of maximum precipitation.

Part IV—Arrangement of a Climatography. An outline of the content and arrangement of a complete presentation of a climate.

While it will be inevitable that a few readers will be disappointed by omission of special techniques of one sort or another, it must be emphasized that the successful presentation of a methodology precludes the possibility of an encyclopedic coverage of the vast field here represented.

There are some points that may be considered bad among the many good ones. Mathematical symbols are not always selected with requisite consideration of accepted practice in many of the sciences allied to climatology. The use of "μ" for average deviation, and "f" for probable error will be confusing to some. However, this is the price we must pay for allowing each field to develop its statistical science along more or less independent lines. Probably it is fair to permit the author to make the decisions as to symbols from his

own frame of reference; but one could wish for a larger common denominator of agreement on purely mathematical representation.

Engineers and others who are often called upon to base inferences upon scanty climatological data will be disappointed that no treatment of the small sample has been included. Indeed the book leans heavily upon the concept of statistical parameters for descriptive purposes only; no thorough consideration is given of reliability of the parameters as a result of random sampling, which is so important when predictions are to be made.

These criticisms are entirely minor, and judging the book in the only fair light—that of the author's intentions—it is entirely adequate, and will provide a most satisfying answer to the need for an organized treatment of the statistics of climate. The theory is set forth simply and directly and the current of thought is illustrated by a number of worked examples. The selection of graphs and figures has been done judiciously and these are of great value in the presentation. Often the author rises to heights of lucidity seldom equalled in statistical works; the treatment of the harmonic analysis, for example, is certainly the best to date. Dr. Conrad's book is definitely a "must" for those concerned with climatology.

HAROLD A. THOMAS, JR.

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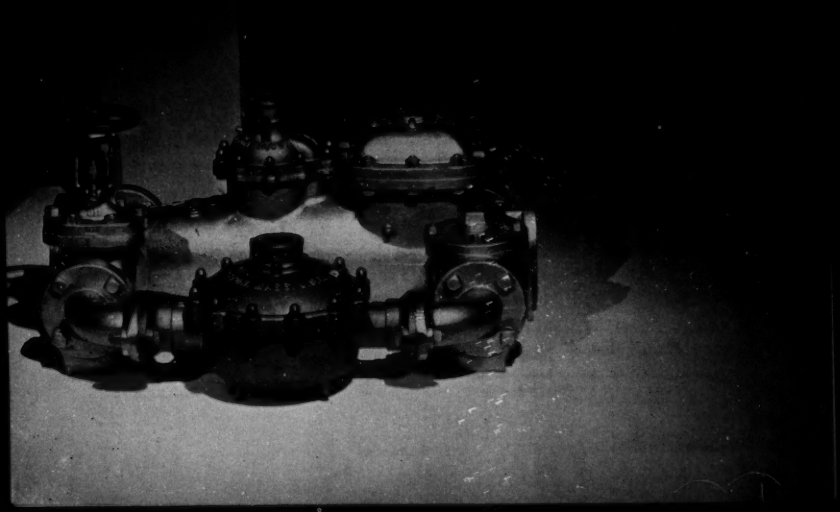

Vol
19

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OMEGA MACHINE CO.
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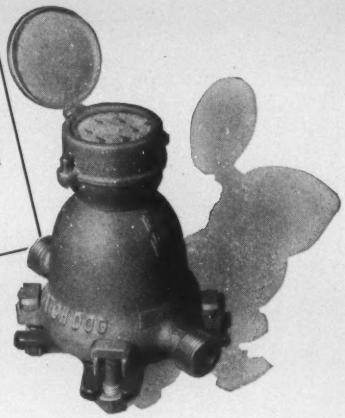
BRONZE CASES *for* WORTHINGTON-GAMON METERS



. . . but Present Government Regulations Limit Use to Small Meters

WAR Production Board Limitation Order L-154 has been completely amended to permit the use of copper for the manufacture of bronze cases for water meters. Bronze will be used for Worthington-Gamon meter cases.

"Watch Dog" Quality Based on Longest Experience, Largest Research Facilities

The oldest water meter manufacturer, Worthington has constantly improved its broad line, to minimize maintenance, and at the same time measure ever smaller quantities dependably, accurately.

The Most Extensive Nation-Wide Service

Another reason why Worthington-Gamon Meters have been specified in the largest U. S. contracts: 24 district offices in 24 leading cities.

★ ★

"Watch Dog" models . . . made in standard capacities from 20 GPM up; frostproof or split case in household sizes. All parts interchangeable with your present meters of our manufacture. Write for Bulletin.

WG4-6

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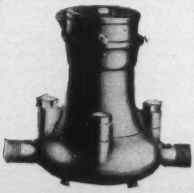
WORTHINGTON PUMP AND MACHINERY CORPORATION

The Meter Specified in the Largest Contracts Ever Awarded in the U. S.

Power Plant Equipment • Turbines & Turbine-Generator Sets • Condensers, Heaters, Ejectors • Water Purification Equipment • Pumps, Stationary and Portable Compressors • Air-Conditioning & Refrigerating Equipment • Power Transmission Equipment • Construction Machinery, Equipment for Mines • Locomotive Feedwater Heaters • Welding Positioning Equipment • Liquid Meters

TWO WARS

have taught the value of Trident Water Meters — "their economy, durability, quality and low maintenance cost," to quote this steady buyer of Tridents for over a quarter-century. So blueprint your future water meter buying wisely.



Investigate Trident Water Meters. Your nearest Trident representative will be glad to give you any facts you may require.

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Resists Corrosion

Has proven practical for nearly three-quarters of a century

Immediate delivery can be made to waterworks on both wrought iron and steel, black or galvanized.

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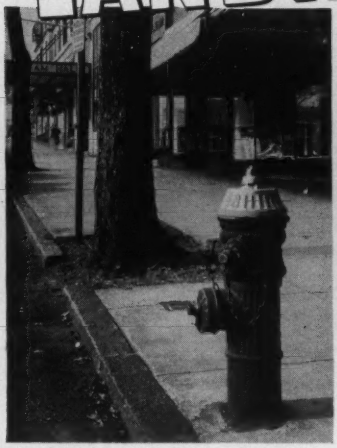
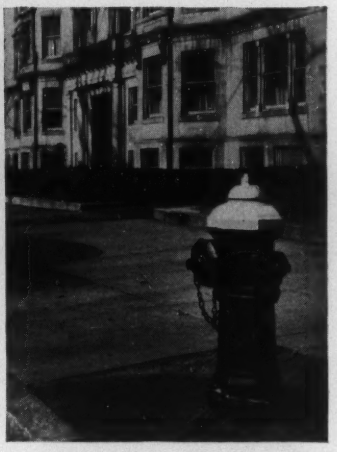


Here a Ludlow List 75 Ludlow Slide Gate Hydrant, installed many years ago, still serves dependably, its good design truly at home amid the modern stores and apartments of suburban Boston.



This Ludlow List 90 Slide Gate Hydrant is of recent design, and is set farther back from the curb, in accordance with modern practice. This current model offers many desirable features worth investigating.

IN HISTORIC BROOKLINE, MASSACHUSETTS LUDLOW HYDRANTS TAKE THEIR TRADITIONAL PLACE IN THE AMERICAN SCENE

YEAR in and year out, Ludlow Hydrants serve on, although installation practice may change, and architectural treatments may vary. The List 90 Slide Gate model is now a general favorite the country over. It insures quick water, proper shut-off without water hammer, correct drainage and easy inspection and servicing. Full information, specifications and costs await your request.

H-5 **The Ludlow Valve Mfg. Co., Inc., Troy, N. Y.**

LUDLOW HYDRANTS & VALVES

SINCE 1866

HYDRO-TITE

AND DRY BRAIDED FIBREX

A DEPENDABLE SELF-CAULKING JOINT COMPOUND FOR CAST IRON BELL AND SPIGOT WATER MAINS

HYDRO-TITE is a self-caulking sulphur base jointing compound used to joint bell and spigot cast iron water mains and soil pipe. It comes in powder form which insures uniformity and quick melting.

When poured into a joint, HYDRO-TITE immediately solidifies upon contact with the metal and bonds to both the surfaces of the bell and the spigot for the entire depth of the joint. It requires no caulking and after pouring a joint, water pressure may be immediately applied.

HYDRO-TITE is easy to use, no skill being required to make joints that are tight from the start. Joints made with HYDRO-TITE will stand any pressure the pipe will stand.

DRY BRAIDED FIBREX

USED LIKE BRAIDED JUTE
WILL NOT BREED BACTERIA

A SANITARY Packing used in jointing bell and spigot pipe for water, sewer mains and soil pipe.

FIBREX was designed for use with Hydro-Tite and other self-caulking compounds, but is entirely suitable also for joints made with lead, and for Sani-Tite and other asphalt sewer joint compounds. Thousands of pounds of Fibrex are already in service on water lines throughout the country.

60 Lb. Reels

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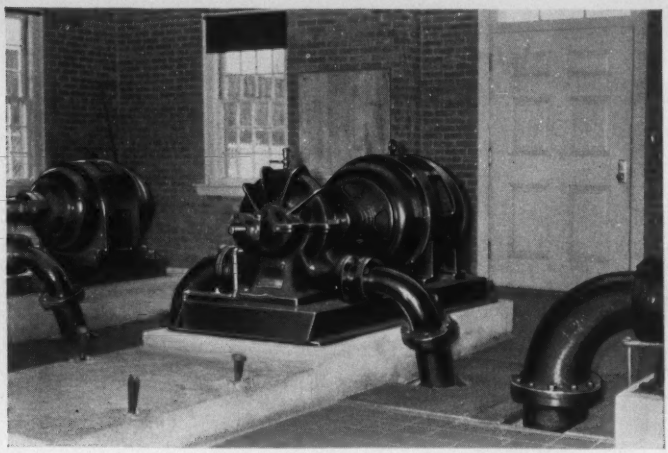

Methuen booster station able to move daily quota of 4½ million gallons with three Fairbanks-Morse centrifugals.

EXACTLY THE RIGHT PUMP

There are no adjustments on a pump. It is designed and built to do one job. At this job it will work efficiently, and at any other it will not.

Fairbanks-Morse builds with the best of materials, workmanship and engineering research. The result is a line of uniformly good pumps. In addition, Fairbanks-Morse takes the utmost care to see that exactly the right pump is chosen for each job.

A Fairbanks-Morse engineer is on call to help you solve your pumping problems. Write Fairbanks, Morse & Co., 178 Atlantic Avenue, Boston 10, Massachusetts.

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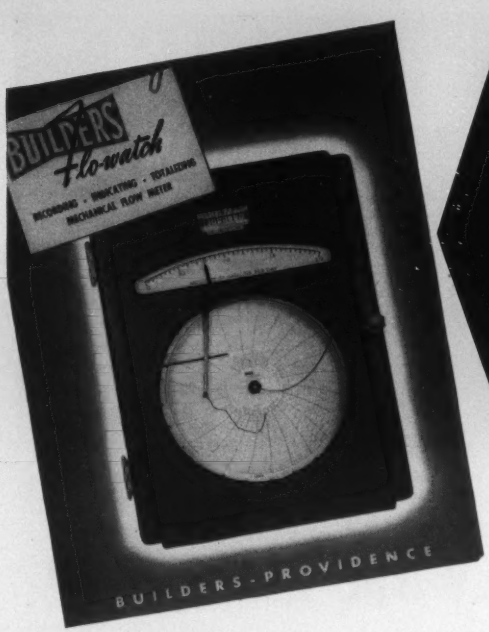

JUST OFF THE PRESS

● Bulletin No. 318B describes Builders Flo-Watch Meter—a precision instrument to measure flow through differential producers such as Venturi Tubes, Kennison Nozzles, orifice plates and over weirs. Flo-Watch records, indicates and totalizes the flow. Available in a variety of mountings and dial combinations. For the Bulletin, address Builders - Providence, Inc., (Division of Builders Iron Foundry), 26 Codding St., Providence 1, R. I.

Sincerely

BUILDERS-PROVIDENCE

. . . But a fire hydrant's Life Also Has a Sterner Side . . .

The children who revel in the refreshing spray from the neighborhood fire hydrant on a hot summer day will have far more cause to be grateful for the presence of the hydrant in case of fire in one of their homes.

You can be SURE that your hydrants are immediately responsive if they are Kennedy SAFETOPS. The simple straight-line mechanism . . . large elbow, valve opening and standpipe . . . wear-resistant and long-lived operating parts . . . and several additional refinements of design assure dependable, trouble-free service.

Bulletin sent on request.

THE KENNEDY VALVE MFG. CO. • ELMIRA, N. Y.

KENNEDY *Safetop* HYDRANT

EDDY

Valves and Hydrants

Distinctive Features of the EDDY Valves

ONLY three parts are moved by the Stem—the ball and the two gates. Each gate is hung from one of the trunnions on the ball. A convex surface at the base of each trunnion fits a concave surface on the back of the gate. This allows the gates to adjust themselves properly to their seats. . . . The gates, being free to revolve on the trunnions, do not always seat in the same position. Gates are center bearing and adjustable. They are forced to their seats with equal pressure at all points. There are two hooks on the ball on sizes 4-inch and larger, which loosely engage with the gates.

Distinctive Features of Our New Swivel Top Hydrants

THIS new hydrant has all the advantages of the popular EDDY fire hydrant, plus several additional features. . . . Nozzles are in a short flanged section of the standpipe, which may be unbolted and turned to different positions. . . . Should the standpipe be broken, only the casting below the swivel head need be replaced. . . . To raise the hydrant to conform to a new grading, simply insert a flanged extension piece below the swivelhead. No digging. To add a steamer nozzle at any time, it is only necessary to replace the swivel head with one having a steamer nozzle.

Besides valves and hydrants to meet the most exacting demands of waterworks service, the complete EDDY Line includes: valves for sewage disposal works; valves for steam, gas and oil; check valves, foot valves, plug valves, shear gates, indicator posts, etc. EDDY valves are made in three classes: Iron Body Bronze Mounted, All Bronze, and All Iron Valves.

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Remember that joints caulked with lead are soft and flexible . . . take up normal pipe movement without leakage . . . stay tighter longer.

Remember, too, that there is no current shortage of lead . . . no ruling which prohibits the use of lead for caulking purposes.

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Many cities have reclaimed thousands of dollars worth of old cast iron pipe by cleaning the tuberculated interior and coating it with a spun lining of Bitumastic 70-B Enamel.

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In many instances this work is done by the Water Department's own labor. In addition to coating materials, arrangements can be made with us for equipment and supervision.

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TO BETTER BELL & SPIGOT JOINTING

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Caulks into joint in a jiffy. Stops leakage; saves water. Invaluable in repairs to branch lines. Works with *Tegul*-MINERALEAD, lead or Portland Cement. Made of tough rubber and is practically permanent. Now available for 4 to 12″ diameters. Write for literature.

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. . . Handling Three Different Deposits

This **MORRIS** HYDRAULIC CUTTER DREDGE

● Assembled, dismantled and moved overland three times — for dredging jobs on three difficult deposits — the Captain George, a Morris 12-inch Portable Hydraulic Cutter Dredge has proved its versatility and mobility.

MORRIS DREDGES *are engineered to attain:*

1. **MAXIMUM OUTPUT by impelling the maximum amount of solids through the pump at a uniform rate.**
2. **MAXIMUM LIFE through rugged construction, accurate machining and interchangeable wearing parts.**

Morris cutters and pumps work in synchronized efficiency. The operating gear, designed for flexibility and ease in manipulation, is reduced to the simplest practicable mechanics. The Captain George is a type of dredge that will cope with the most stubborn deposits—it is adapted to reservoir cleaning, filling low lands, draining low areas, park beautification and general postwar municipal projects.

Write for Special Bulletin 177 giving descriptions, specifications, and recommendations on hydraulic dredging plants.

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Branch Offices in Principal Cities

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DE LAVAL

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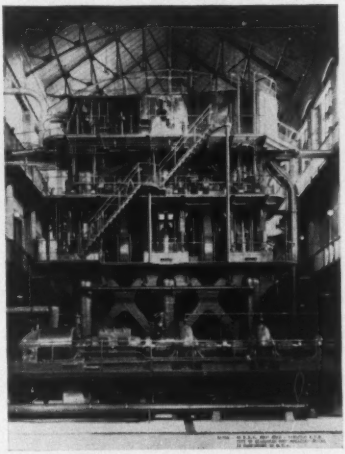

City of Milwaukee, Wisconsin,—30 MGD Reciprocating Engine and 40 MGD DeLaval Geared Centrifugal Pumps.

The reciprocating High Duty Water Works Pumping Engine shown has operated for many years with high economy and great reliability. The DeLaval Geared Turbine Driven Water Works Pump in the foreground has one-third greater capacity, equal reliability and based on lower first cost, space requirements and high economy, will pump water at lower operating cost.

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Chlorination
that BLANKETS
the reservoir bottom!

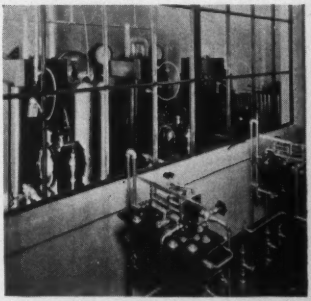
ENDS TASTES AND ODORS AT BALTIMORE

PERSISTENT tastes and odors at Baltimore's Lake Ashburton distribution reservoir have been brought to an end by continuous chlorination of the entering water to maintain a high residual in the water beneath the surface. Organic deposits on the rough bottom "could not be cleaned out." But now they are "blanketed" by the high residual in the lower strata of water and no longer affect taste and odor of the finished water.

Gordon L. O'Brien, Designing Engineer, Baltimore Bureau of Water Supply reports*: "This system has been so effective that we have adopted it in our other reservoirs where circulating lines exist."

Previously, only the reservoir effluent was chlorinated. Now the effluent needs only a small amount of chlorine to maintain a residual of at least 0.5 ppm in the mains.

The prompt solution of the problem at Ashburton was made possible by the existing installation of W&T Automatic Chlorinators. As Mr. O'Brien reports, "No attendants are regularly kept at these stations." The capacity and flexibility of the installation—permitting full-scale treatment of water entering or leaving, as desired—made this unusual corrective practical.



*"Taste and Odor Control by Reservoir Chlorine Blanket" by Gordon L. O'Brien, Designing Engineer, Bureau of Water Supply, Baltimore, Md. Water Works Engineering, Vol. 96 No. 18. A reprint of this article is yours for the asking.

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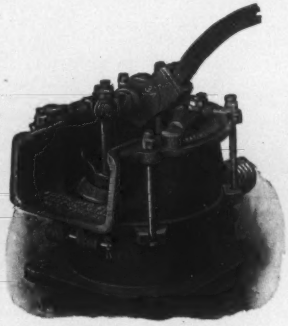

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Special Castings *Short Body B. & S. Specials*
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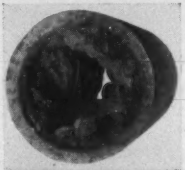

Get Full Service From Old Mains

The most practical way to meet today's overload demand is to clean clogged water mains. FLEXIBLE Underground Pipe Cleaning Co., specializes in such jobs— any size—2″ to 72″.

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41 GREENWAY, HAMDEN, CONNECTICUT

New England Representative

Pipe Founders Sales Corporation

CAST IRON PIPE AND FITTINGS

FOR

Water, Steam, Gas and Culverts
Special Flanged and Bell and Spigot Castings
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The Journal of the New England Water Works Association
and OTHER good publications.

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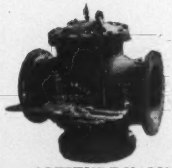


Controls elevation of water in tanks, basins and reservoirs

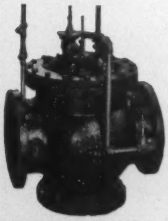
ALTITUDE VALVE

1. Single Acting
2. Double Acting

Maintains desired discharge pressure regardless of change in rate of flow

REDUCING VALVE

Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



Maintains levels in tank, reservoir or basin

1. As direct acting

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

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A self contained unit, with three or more automatic controls

COMBINATION VALVE

Combination automatic control both directions through the valve.

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SURGE-RELIEF VALVE

Electric remote control—solenoid or motor can be furnished

REMOTE CONTROL VALVE

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

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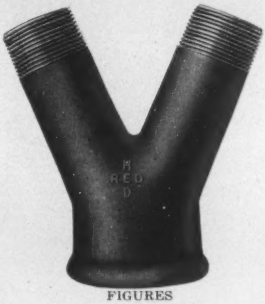

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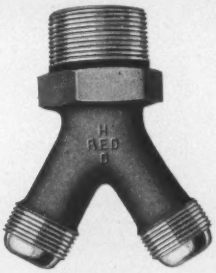

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440M—440FM

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Manufacturers of

RED HED Brass Goods for Water Works

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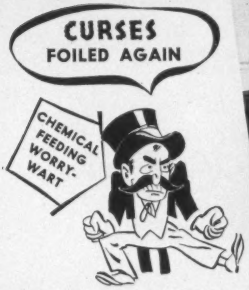

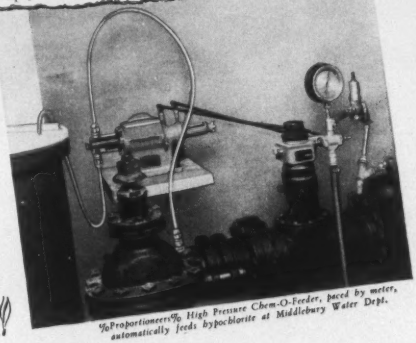

%Proportioneers% High Pressure Chem-O-Feeder, paced by meter, automatically feeds hypochlorite at Middlebury Water Dept.

End your water treating problem with %Proportioneers% Chemical Feeders and Hypochlorinators . . . treat your water supplies automatically! The High Pressure Chem-O-Feeder, shown above, starts, varies and stops dosage of chemical as the water comes on, fluctuates and tapers off. The meter control prevents dangerous undertreatment or unpleasant taste resulting from wasteful overtreatment. Hydraulic operation of Chem-O-Feeder insures unfailing operation, without the use of electricity or other power source.

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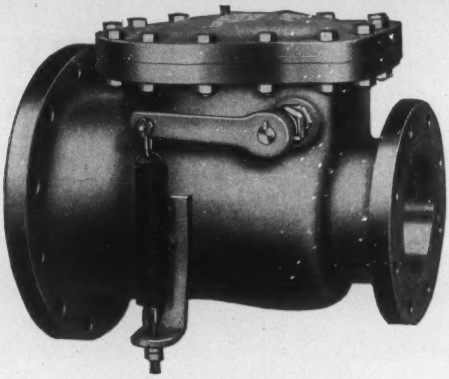

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LIST 340A

Clearway Quiet-Closing Check Valves eliminate "SLAM"

Made in straight-thru type, as well as expanding outlet type for bolting direct to pump discharge.

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Herbert H. Crowell, *Sales Mgr.*

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SMITH VALVES AND HYDRANTS *Available NOW!*
for Maintenance NEEDED NOW!

Recognizing the *necessity* for adequate maintenance of the nation's water supply systems, the W.P.B. has, since the beginning of the war, authorized the production of certain needed water works materials, including valves, hydrants, and maintenance equipment. Thanks to this far-sighted policy, the A. P. Smith Manufacturing Company is now in a position to offer prompt shipment of:

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Gate Valves

Tapping Sleeves and Valves

And other Smith water works equipment

There's no reason to let your system run down or to deny adequate service and protection to the communities you serve. Do your needed maintenance work now and take advantage of the availability of Smith products.

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CHECK VALVES
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TAPPING SLEEVES AND VALVES
WATER SERVICE BRASS GOODS

THE A. P. SMITH MFG. CO.

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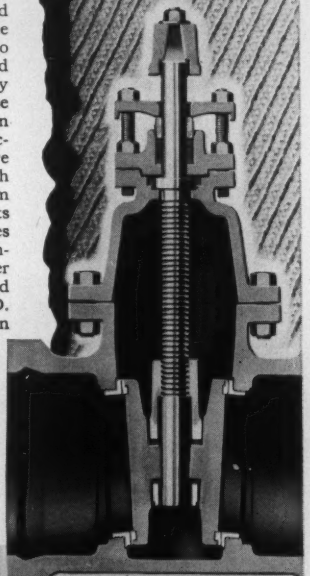

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Established in 1803

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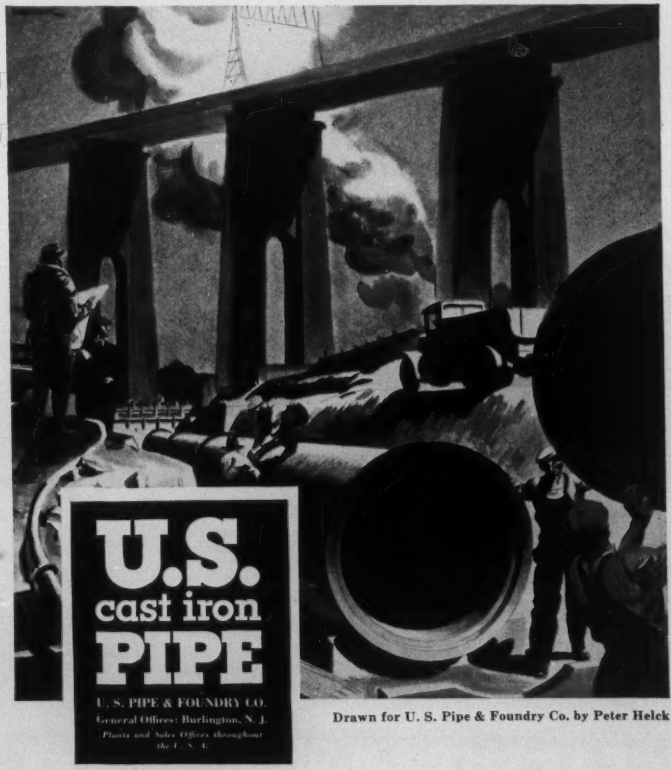
IF your present or postwar plans call for large diameter pipe and special fittings why not avail yourself of the advisory service of our technical staff? Out of our long experience we are frequently able to suggest adaptations of design principles which have proved efficient and economical in other installations. Our facilities are extensive and include a specialized plant for the production of fittings.



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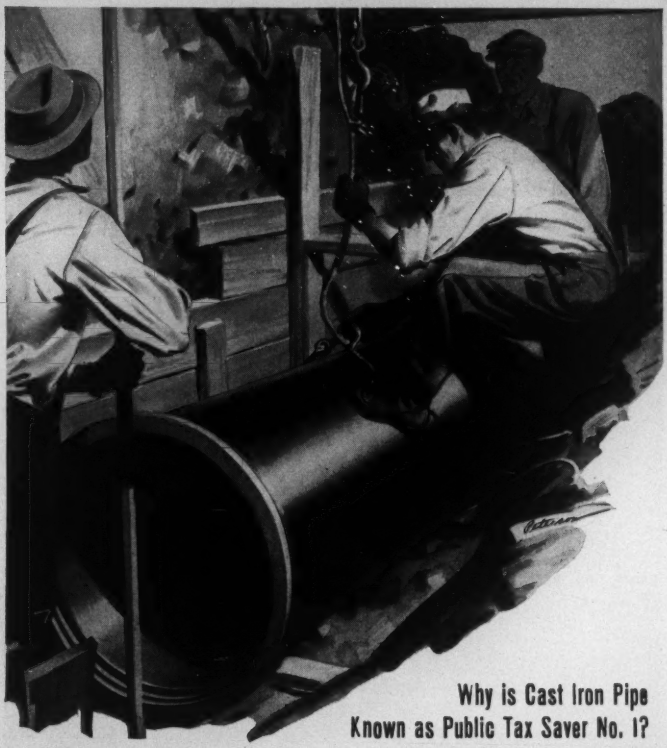

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CAST IRON PIPE SERVES FOR CENTURIES

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is a quarterly publication, containing the papers read at the meetings, together with reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness.

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Tested and used for over 40 years,
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